RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XX.

Published by order of His Excellency the Governor General of India in Council.

CALCUTTA:
SOLD AT THE OFFICE OF THE GEOLOGICAL SURVEY,
(AND BY ALL BOOKSELLERS).
LONDON: TRÜBNER & CO.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1887. [February.

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1886.

South India. *Mr. Foote.*

For the past three field seasons Mr. Foote has had the Madras Presidency all to himself. This came about in the course of a perfectly natural selection in the distribution of a limited staff according to the urgency of demand, whether practical or scientific. In the early days of the Survey the whole staff was for several successive years engaged upon the coal-fields, and ever since continuously several geologists have been so engaged, but Madras is not favoured in that line, the Gondwána coal-measures being only found in a part of the Godavari district. For other reasons, however, Madras very early received our best attention. In taking up a new country the rational method of geological enquiry was to get hold of such formations as offered, through their fossils, the means of establishing correlations with known rocks, and from those fixed horizons to obtain indications as to the ages of contiguous deposits. In this way the best part of the Survey staff were, at the beginning, for several years engaged in Madras; and the proportion was fairly kept up until nothing was left but the immense residuum of fundamental gneiss and the oldest schists that locally accompany it; while other parts of India offered more promising fields of research for the final solution of the total complex of formations in Peninsular India. This accounts satisfactorily for Mr. Foote's recent isolation; but the local authorities only recognised the isolation, and remonstrated against it, so it has been decided to add Mr. Fedden to the Madras party of the Survey. Before going on furlough, Mr. Fedden had finished his survey of Kathiawar, and I had intended him to take up new ground in the Rewa Kanta districts of Guzerat, but he has now begun work on the gneissic rocks of Vizagapatam. Results are very slowly acquired in rocks that are so obscure and so extended. Mr. Foote during last season mapped a considerable area in extension of his previous work in Bellary, both of

gneiss and of his Dharwar schistose series. He suggests a probable correspondence of a large part of the gneiss with that of Bundelkhand, long ago distinguished as older than the prevailing gneiss of Bengal. It was then also shown that the gneiss east of Chaibassa, in Singhbhum, is probably of the same age as that of Bundelkhand (Manual, p. 21).

Mr. Foote resumed his survey in Bellary at the beginning of the current season, but he has since been deputed to report on some gold-fields in Mysore, at the solicitation of the local authorities. Although these interruptions to our regular work are somewhat perplexing, it is right that the best knowledge and experience should be made available for the furtherance of practical objects.

THE KARNUL CAVES.

We have now published in admirable form by Mr. Lydekker in the Palæontologia Indica the detailed description of the fauna of the Karnul caves, discovered and so carefully explored by Mr. Foote and his son, Lieutenant H. Foote, R.A. If the results were disappointing in respect of what was most hoped for—prehistoric human relics (though upon this point I believe Mr. Foote has still a word to say regarding certain cut bones)—the general results are of considerable interest. As to the age of the fauna, Mr. Lydekker remarks:—"The comparatively large number of species either totally extinct, or which are not now found living in India, renders it probable that the age of a considerable part of the Karnul cave deposits is not newer than pleistocene; and the fauna, as being almost certainly more recent than that of the Narbada beds, may be provisionally assigned to the later part of that period." The numerous affinities with African types is a feature previously noted regarding the Tertiary (Siwalik) fauna of India.

CHHATTISGARH.
Dr. King.
Mr. Bose.
Mr. Hira Lall.

Dr. King's regular work in the hills west of the Chhattisgarh plains was necessarily much interrupted by his having to superintend the coal explorations in the fields far to the east. The results of those trials were published in the Records for November, and it has to be regretted that the Rampur field, which is the one crossed by the new line of railway, does not promise a fair supply of fuel. The trials were all by borings, but the samples of each seam were taken very carefully foot by foot, and separately assayed. The amount of ash in almost every case was prohibitively high, from 30 to 50 per cent. In only one seam, in the Baisandar valley, the average was 21 per cent. of ash, the 5th, 6th, and 7th feet giving only 6·52, 12·08, and 18·68. Thus it may yet be possible to get small local supplies from some of these seams, and no doubt this will be attempted by shafts when the demand comes to be pressing. Meanwhile the exploration is being carried on in the nearest ground to the north, in the Mánd valley. In the remote hill country, far to the north of Korba, a large new coal-field was traced out by Sub-Assistant Hira Lall: it is the western extension of the measures noticed some years ago by Mr. Ball at their eastern extremity as the Lakanpur field.

The relations of the rocks forming the plains of Raipur to those underlying them on the west is still under examination. Dr. King describes the bottom sandstone of the Raipur series (? Lower-Vindhyan) as resting with partial unconformity on shaly beds of the Chilpi series—general parallelism of dip at low angles with local overlap and discordance—a like relation to that described by him between the Karnul and Kadapa formations, or even between the separate groups of the Kadapa

series. It seems as if the chief difficulty would be with the lower members of the Chilpi series in connection with igneous and schistose rocks. Dr. King reported upon Mr. Bose's work as still exhibiting the want of observation and study that had been found fault with in previous seasons; I may however add, that since going to the field this season Dr. King has written less unfavourably of Mr. Bose. I only hope he has not been beguiled.

SOUTH REWAH.
Mr. Hughes.

Mr. Hughes' deputation in charge of the Umeria colliery did not terminate till the end of December (1885), and for the rest of the season he was engaged in examining the rocks above the coal-measures, and succeeded in finding some new localities for fossils in them. At a few miles to the west, on the Son-Máhánadi, the Jabalpur beds (top Gondwána) are typically represented, and the problem is to make out some distinctions in the variable thickness of sandstones shales and clays between those beds and the coal-measures, representing what in other fields constitute quite two-thirds of the Gondwána system. The most marked stratigraphical boundary in the whole basin is that just above the coal-measures, as was formerly observed in the Warda-Godavari basin; yet in neither case does it seem to involve a correspondingly marked change in the fossils, for a considerable thickness of beds above that boundary still contain distinctively lower Gondwána forms. Mr. Hughes has already seen a great deal of those upper rocks, having been at work in Rewah since 1879; and in the north-central portion of the basin he hit upon some fossils marking distinctly the Kota Maleri and Denwa horizon; so it is altogether very disappointing that he has not yet offered any clue to an interpretation of the stratigraphy where it presents any difficulty. On this account, lest we should hopelessly lose any benefit from the extensive acquaintance Mr. Hughes should have acquired of that ground, it was with much reluctance that I recently consented to his deputation for the present field season to the Nizam's territories, to conduct exploration for minerals; but practical objects must, I suppose, claim precedence.

THE CHHINDWARA COAL-FIELDS.
Mr. Jones.

During the past season Mr. Jones completed the survey of the southern coal-fields of the Satpura Gondwána basin. There are altogether eleven separate areas where the coal-measures group is exposed, seven of them being in the Chhindwara district. The four adjoining areas in the Betul district were mapped and described some years ago (Rec., VIII, 1875). The intended exploration of the seams by trial borings in connection with the survey not having been carried out, the information regarding the prospects of the field is little better than before, the principal outcrops having been already reported on long ago. Mr. Jones has now given a full account of all the exposures and defined the limits within which there is any chance of finding coal. On the whole, the quality of the coal, so far as it can be ascertained from outcrop samples, is not very encouraging. The report and maps are now at press. As a geological study of a very interesting region, Mr. Jones' report is disappointing, through defect of critical observation and discussion on the ground, for it is futile to expect to solve stratigraphical puzzles by the colligation of field notes; the problems must be stated, and to a great extent solved on the spot; the description of them is then a simple matter. The failure to find a single recognizable fossil during two seasons' work on these coal-measures is similarly unsatisfactory.

This piece of work corresponds to Mr. Hughes' description of the southern coal-fields of the Rewa Gondwána basin; and here, as there, the chief puzzle remains—to put in order the main mass of Gondwána strata above the coal-measures. A preliminary attempt at this was made in 1873 (Memoirs, Vol. X).

RAJPUTANA. *Mr. Hacket.*

For a great part of last season Mr. Hacket was engaged in endeavouring to clear up the perplexities of the Arvali rocks by a further study of them on their eastern margin, about Chitor and Neemuch, where they are in contact with an archæan gneiss. In this ground in 1881, as was noticed in the annual report for that year (Rec., XV., p. 3), Mr. Hacket made out that the sandstone of Mundsaur, which had originally been taken to be Vindhyan, as occurring close to these rocks and quite like them petrologically, was really identifiable with the highly metamorphic Delhi quartzite (see Rec., XVII, 103) so extensively exposed in the north-east of the Arvali region. This implied a wide distinction of this member from the schists with which it is generally associated throughout the region, and of course a complete separation from the Vindhyans, which are elsewhere quite unaffected in immediate proximity with the Arvali slates. Mr. Hacket now extends this identification so as to include the Arvali schists: the sandy calcareous conglomerate resting on the gneiss near Dhaulapani (20 miles south-west of Neemuch) and containing pebbles of that rock, passes below the limestone and shales that underlie the Mundsaur sandstone, and these also are traceable to the north continuous with the slates, schists, and limestones of the Arvali series. Thus the partial break in that series, as established in 1881, is a good deal modified, and we now seem to have representatives of the whole metamorphic series of the Arvalis (so far as at present made out) in unaltered original contact with an archæan gneiss of the peninsular area, as if sheltered in a bay of that most ancient land from the contortion and metamorphism that took full effect upon the same deposits in the main area to the westward. The western boundary of this old gneiss is very obscure, owing to the changed condition that rapidly supervenes in the newer rocks on that side, where they are extensively transformed into a schistose gneiss. In confirmation of this distinction of two gneissic formations, Mr. Hacket describes the occurrence of boulders of gneiss in the schistose gneiss at the village of Mandkhola (Lon. 74°-34′, Lat. 24°-7′), but the observation needs critical petrological confirmation. The re-connexion of the Delhi quartzite with the Arvali series is more in harmony with the fact of their association over so large an area; but Mr. Hacket considers that there is probably some unconformity, for the massive quartzite is locally in contact with different rocks of the underlying series; this, however, might be due to faulting where the strata are so greatly disturbed. The gradual change from the quartz veins so abundant in the slates of the eastern part of the region (as east of Deoli) to the granite veins that similarly pervade the schists of the central zone, is a noteworthy feature. On the other hand, Mr. Hacket notices patches of comparatively unaltered slates within the area of the schistose gneiss, as close to the east of Oodeypore, and again on the west side of the Arvali range east of Mera (close to the north of Abu); but these may only be, as Mr. Hacket suggests, freaks of partial metamorphic influence within the same rock series.

The stratigraphical relation now brought forward of the Arvali series to the old

gneiss, brings it into nearer comparison with the Bijawar (transition) series of the Peninsula which rests in like manner on the south margin of the Bundelkhand gneiss. The characteristic breccias of the Bijawar area and the Narbada valley are not represented in the Neemuch sections, but the absence of such peculiar rocks may not signify, so the wide correlation may be provisionally accepted. The other pre-Vindhyan formation, the Gwalior series, resting on the northern margin of the Bundelkhand gneiss and not specifically identifiable with the Bijawars but having some points of affinity with the lower-Vindhyan and the Kadapa, was found characteristically represented in the Arvali area at Hindown, and subsequently Mr. Hacket made it out to be a member of his Arvali series (Rec., XII, p. 24). We thus seem to have in this region, on the north-west border of the Peninsula, an extensive exhibition of a great system of very ancient rocks that occur locally in various parts of the peninsular massif.

We are still however very much in the dark upon the details of the relations and homotaxis of this immense sequence of formations (including the Vindhyans), all having as yet proved azoic. No unconformable break could be more marked than that of the typical lower-Vindhyans and the Bijawars throughout the Son valley; yet here in the Neemuch district we seem to have members of the older series that were originally by petrological characters and stratigraphy placed with the adjoining upper-Vindhyans. Thus there is unlimited room for the discovery of 'mistakes,' than which nothing is more gratifying to the average human being; so the present apparent anomalies of the situation are here broadly indicated to stimulate the ardour of future explorers.

Mr. Oldham.

Mr. Hacket's work in Rajputana has been confined to the older rocks, the Arvalis and the Vindhyans, to the west of which, in the more or less desert country of Jesalmer, the existence of fossiliferous limestones has been known for many years. Mr. Blanford made a traverse of that ground in 1876, from Jodhpur to Rohri on the Indus, and noted a succession of jurassic strata more or less corresponding to those described in Cutch, and of course they are also the marine representatives of some of the Gondwána system. They are surmounted by tertiary (nummulitic) limestones and clays. During last season Mr. Oldham was deputed to explore the northern extension of those rocks towards Bikanir. He found that at about 25 miles north of Jesalmer the nummulitic strata sweep round eastwards passing northwards under the desert of Bikanir. But the most interesting of his observations was that the boulder rock of Pokaran, which had previously been taken to be Vindhyan (although recognized as of glacial origin), must really be the Talchir boulder bed, occurring as that bed so constantly does upon a denuded surface of very ancient peninsular rocks, and forming by position the base of the sequence of mesozoic strata occurring at some distance to the west. As the Talchir group forms all over India the base of the Gondwána coal-measures, Mr. Oldham suggested that there was room in the covered ground between the boulder bed and the marine jurassics for a possible occurrence of coal-measures, with coal. The fact of there being a continuous sequence of marine strata on this horizon in the Salt-range is not in favour of the conjecture, but neither does it forbid it. Mr. Oldham was not very sanguine of success, but in view of the great want of coal in that quarter of India the question was worth looking into. This is now being done; and the latest information is not encouraging: in a

letter dated 1st January Mr. Oldham informs me that he has in some places found upper Gondwánas overlapping unconformably on the Talchirs.

Mr. Kishen Singh.

Sub-Assistant Kishen Singh has completed the work he has been engaged on for some seasons, to map the upper-Vindhyans of the Chambal basin. The ground was very imperfectly known, from a single traverse made some years ago by Mr. Hacket to fix approximately the northern boundary of the trap of the Malwa plateau. The continuous survey has brought out some unimportant corrections. The sandstone of Jhalra Patan which had been taken to be Rewah sandstone (upper-Vindhyan) is shown by Kishen Singh to pass beneath the shales and limestones that underlie the Kaimur sandstone and is so proved to be lower-Vindhyan. None of the peculiar lower-Vindhyan beds, such as the Tirhowan breccia of the Bundelkhand area, or the porcellanic and trappoid beds of the Son valley, have been observed in Malwa. Kishen Singh has now been transferred to map the boundary of the Deccan trap in the Mandla and Seoni districts.

ASSAM.
Mr. La Touche.

Mr. La Touche made good progress with his work in the Garo Hills during the past season. Although the structural features are not obscure, progress is greatly impeded by the dense vegetation and the scarcity of fossils in the sequence of tertiary rocks above the nummulitic horizon. Mr. La Touche's progress report is published in the current number of the Records.

HIMALAYAN REGION.
Mr. Middlemiss.

During this year again Mr. Middlemiss has been alone in the Himalayan region, and he has done excellent work. His genuine enthusiasm and thoroughness are most refreshing, his real aim being, not to make a display, but to understand. The account of his work is given in the current number of the Records; it was fully ready for publication in October last, but had to be deferred for more urgent though less important work. His ingenuous exposition, and illustration from a local instance, of the 'folded flexure' (to use the older and neater term originally given by Professor H. D. Rogers)[1] and its attendant 'reversed faulting,' and of their function in the formation of 'true mountains,' will be instructive to many. Mr. Middlemiss' paper describes a very complete geological feature, about 45 miles in length, immediately east of the Ganges and at the edge of the Lower-Himalayan region, just inside the fringing zone of Sub-Himalayan rocks. It is in the main a long ellipse of crystalline schists surrounded by a narrow fringe of newer strata. To mark how backward we still are (malgré nous) even in the superficial knowledge of large tracts of country, it has to be confessed that this description came as a surprise. In previous notices of this region it has been stated that although the Lower Himalaya begin with a great spur of crystalline schists and gneiss reaching to within 7 miles of the Sub-Himalayan zone between the Beas and the Sutlej, the predominance of crystalline rocks in it comes on in eastern Kumaun, on the frontier of Nepal; but we now see those rocks already established in force close to the east of the Ganges and at the very edge of the region.

Mr. Middlemiss now puts us in possession of a more or less detailed description of a third detached section of the Lower Himalaya. This apparent want of system and continuity of work has already been duly explained by the advantage of taking up ground of which fair maps are available, and this only occurs in the purely British

[1] Memoirs, Vol. III, pt. 2, pp. 194-5.

districts. But indeed there may be some compensating advantage in these independent studies of adjoining areas, the adjustment of discrepancies being perhaps more likely to give true results than might have been attained in any endeavour to carry out over a large area a scale made out in a part of it. In the present case the discrepancies are considerable, and it will be well to exhibit them in juxtaposition. The first of the sections referred to is that in the Simla area at the west end of the Lower Himalayan region, where there is the widest display of unaltered rocks. The work there was mine (1859-62),[1] and it has least claim to consideration, for it made no pretence to be a survey; the map was a poor one, on a small scale, and the observations were made from cursory traverses of the ground in connexion with a more careful study of the Sub-Himalayan zone, which was really the work in hand, the area covered being evidence to the point. The second area, 30 miles east of Simla, was by Mr. Oldham (1883)[2] with the new map of Jaunsar. The third area is 30 miles further east, in Garhwal, by Mr. Middlemiss, now published. I have placed the groupings below in parallel columns, indicating any suggested correlations. In the first column I give Stoliczka's conjectured affiliation of the Simla sequence (from his own observation) with that in Spiti.

Spiti.	Simla.	Jaunsar.	Garhwal.
Lilang	Krol (limestone).		
(upper trias).	Infra-Krol.		Tál (mesozoic).
	Quartzite.		Massive limestone.
Kuling	Carbonaceous shales.	Bawar.	
(carboniferous).		Mandhali.	
		Deoban (limestone).	
		Chakrata.	Purple slates.
		Limestones and slates.	
Muth	Blaini		
(upper silurian).		Volcanic beds.	Volcanic breccia.
Upper Bhabeh	Simla slates.		
(lower silurian).			Schists.

The chief discrepancy is between the sequences of Simla and Jaunsar, Mr. Oldham asserting provisionally that the rocks in either have no representative in the other (*supra*, xviii, p. 4). The horizons he does suggest are indicated in the table: that the Bawar represents part of the infra-Krol; that the Deoban limestone is much older than the Krol limestone (they had previously been supposed the same); that the Blaini is newer than the Lower Chakrata (volcanic beds). Mr. Middlemiss refrains from correlations, not even saying whether his massive limestone may be Krol or Deoban, with the apparent notion that all may yet prove to be one and the same. It would be futile to speculate upon identifications that will in due course be settled by actual survey, but there is one theoretical question upon which I wish to offer a reflection. That the Simla section does not represent a conformable sequence, is a statement I should never have disputed under any strict meaning of the term 'conformable'; but among the several inferences I ventured to put forward one had appeared to me on the ground as very remarkable—the parallelism of stratification between the newest and the oldest formations. The most striking instance

[1] Memoirs, Vol. III, pt. 2.

[2] Records, Vol. XVI, p. 193, with subsequent corrections, Vol. XVIII, p. 4.

given was that of the nummulitic with the infra-Krol beds at Subathu, where throughout a considerable synclinal fold a characteristic bottom bed of the Subathu group coincides with the bedding of the underlying slaty shales. The denudation-unconformity here involved is, of course, prodigious; but the agreement in stratification is only the more remarkable, and it is constant at this horizon throughout this zone of extreme contortion to the north-west, and is still preserved, with little disturbance, in the Salt-range. The interpretation I ventured to put upon this fact seemed one of considerable importance in the history of mountain formation—that in this zone at least little or none of the contortion peculiar to mountain structure had yet affected the old slates at the beginning of the nummulitic age. It was, and is, inconceivable to me that strata which were originally highly discordant could by any play of subsequent contorting action be brought into parallel contact, even exceptionally, much less throughout a great area. A similar parallelism seemed to me to obtain throughout the Simla section. My successors have treated this suggestion with silent contempt; extreme and wholesale unconformities (meaning of course the original relation) have been freely introduced. I have myself indicated a fact of mountain-growth (Manual, p. 550) that would at least locally reconcile such discrepancies—how complete conformity and utter discordance may grow together side by side—but for actual original contact-sections the inference I drew still seems to me rationally binding, and I would call upon my successors to apply it or refute it.

TRANS-FRONTIER.
Mr. Griesbach.
Dr. Giles.

Mr. Griesbach reached India on the 1st November with the Afghan Boundary Commission, not much the worse for the two years' journeyings. His notes on Turkistán appeared in the Records for November, and notice of his return traverse from the Oxus to India is published in the current number. The former was a prolongation eastwards on the strike of the formations previously noticed, where they form the Tirband-i-Turkistán, the principal north-western flanking range of the Afghan mountains. The upper cretaceous limestone assumes quite a predominant place, resting unconformably on the older jurassic and triassic strata, which only appear where exposed in the axes of denuded anticlinals. The lower flanking hills expose a great thickness of tertiary strata dipping at high angles beneath the deposits forming the plains of Turkistán. In connexion with the latter Mr. Griesbach notices an apparent continuation of the same elevatory action now going on in the plains south of the Oxus, attributed to a flexure in process of protrusion by lateral pressure. The evidence for the fact itself, as thus explicable, is only indirect, and perhaps needs confirmation by actual levelling. At the eastern end of the Tirband range better sections were obtained of the older rocks, in the lower members of which some extensive coal-measures were discovered; and Mr. Griesbach reports the important fact that the bottom conglomeratic beds of the series (presumed to be Talchirs) as observed near Herat are found in the Bamian sections associated with beds containing marine carboniferous fossils, thus giving further evidence, were any more needed, of the carboniferous age of the early Gondwána deposits.

For those on the look out from the Himalayan side Mr. Griesbach's notes of his traverse from Turkistán to India seem a little surprising, though perhaps his previous sections of the western prolongation of the Hindu Kush should have suggested the event. He crossed the Hindu Kush by the Chahárdar pass, north-west of

Ghorband, where the range is represented as in full force, but on the whole section up to Peshawar he found no rock that he took to be older than carboniferous. There were in the axis of the ranges immense intrusions of the syenitic granite, already noticed far to the south and west, and with it a considerable exhibition of metamorphosed rocks, but these were all taken to be carboniferous or newer. It is noteworthy, as consistent with the rest, that the axes of disturbance maintained the predominant east-west direction throughout, even where the Hindu Kush of the maps trends north-eastwards.

The Himalayan point of view mentioned above will be best illustrated by a notice of the contemporaneous observations made by Dr. G. M. Giles in the country beyond Gilgit. On the Himalayan side, it will be seen from Mr. Lydekker's map of the Kashmir territories (Memoirs, Vol. XXII), that the whole of the north-western quarter (Gilgit, Astor, and Baltistan) is a geological waste, a few patches of jura-trias, carboniferous, and silurian formations isolated upon a great expanse of crystalline metamorphic rocks which, though probably including some converted palæozoics, were taken to be largely made up of older (? archæan) gneiss, the continuation of that forming the Ladak axis. Dr. Giles does not pretend to be a geologist, but he made some excellent observations of the physical features of the ground traversed, which included a very large area, from the Pamir through Wakhan and eastern Badakshan (across the Hindu Kush, at its supposed roots), and back through Chitral and Yassin. From the very poor specimens brought back by Dr. Giles it would be inferred that the whole of that large area presented only an extension of the conditions known in Baltistan: no trace of a fossiliferous rock was seen, crystalline and schistose rocks greatly preponderated, with only a few less altered slaty specimens. Dr. Giles further observed that throughout the greater part of the area, the eastern and central, an east-west strike was very constant; while on the west side, *i.e.*, on what is represented as the strike of the Hindu Kush, the prevailing strike of the rocks was north-south, though often irregular. Geologists will understand how indefinite must be the inferences from such data, but there seems at least a distinct contrast brought out, where some at least looked for a tie. There remains about 100 miles of unknown ground (Kafiristan) between the nearest parts (Charikar and Chitral) of the areas under notice, but the notion of structural (axial) continuity seems altered: as if the relation of the Perso-Afghan system to the great (?) archæan massif of the Pamir was quite different from that of the Himalayan system to the same, the latter being direct (axial) and the former only secondary (fringing); so that the only structural continuity between the two systems is to be found in the narrow stratigraphical isthmus (or strait), in the centre of which stands Attock on the Indus.

The Llhassa Mission.

Geology will certainly be the chief loser by the indefinite postponement of the proposed Mission to Lhassa. It had been settled that Mr. Oldham was to have gone as geologist, and I have no doubt he would have made the best use of his opportunities.

Publications.—There was no issue of the Memoirs during the present year. These are only occasional publications; when some special area, involving several seasons' field work, happens to be completed, or some other work of greater length than can conveniently find place in the quarterly Records. A Memoir on the Chhindwara coal-fields is now in the press, and Mr Griesbach's Himalayan Memoir is well in hand.

In the Records for 1886, being Vol. XIX of the series, there are 24 papers, with numerous maps and plates. Some of the papers were of considerable interest to geologists beyond the range of India.

In the Palæontologia Indica it has happened that several works have come to a natural close, or check, with the end of the year, and it may be expected that under present financial tightness this branch of our publications may not be so active as for the last few years. Mr. Lydekker has now pretty well cleared off all our fossil Vertebrata, but of course further collections will be made in due course from the same formations. The following parts of series X, the Tertiary and Post-Tertiary Vertebrata, were issued in 1886: Vol. III, part 7, Siwalik Crocodilia, Lacertilia and Ophidia; part 8, Tertiary Fishes; Vol. IV, part 1, Siwalik Mammalia (Supplement); and part 2, the Fauna of the Karnul caves. A catalogue of the Siwalik Vertebrata in the Museum, by Mr. Lydekker, was also published (in two parts). The Survey may be proud of having introduced Mr. Lydekker to a line of work in which he has already earned much reputation.

With the fasciculus on the Echinoidea of the Makrán series of the coast of Biluchistán and of the Persian Gulf, published in 1886, Professor P. Martin Duncan, F.R.S., has completed a very portly volume, forming Vol. I of Series XIV—the Tertiary and Upper Cretaceous fauna of Western India. Dr. Duncan's work comprises the Corals and the Echinoidea of the Sind collections, all the rest of which remain to be worked out.

Dr. Waagen too has well nigh finished his great volume on the fossils of the Productus limestone of the Salt-range. Part 6, the Cœlenterata, was issued in 1886, and a good part of the text and plates of the remaining small fasciculus on the Hydrozoa is in hand for publication. The whole will form a text of about 1,000 pages with a large volume of plates. This will be about half of the projected work on the Salt-range collections now in Dr. Waagen's hands. The remaining volumes will each be scarcely half the size of the first one: Vol. II, on the fossils of the Ceratite beds, and Vol. III, on the fossils of the Newer Mesozoic formations, as indicated in the introduction (p. 3.) to Vol. I. The fourth volume, in three parts, will give the full discussions of the palæontological and geological characters of the respective formations. Dr. Waagen's last renewal of engagement terminated with the year under notice; but it is earnestly to be expected that Government will sanction an arrangement that will permit of his completing this very important work.

A last part of Vol. IV, Series XII, was also issued at the end of 1886, on the fossil flora of some coal-fields in Western Bengal; and in the introduction to the volume Dr. Feistmantel gives a review of the recent discussions on the correlation of the Gondwána system. For the flora itself, Dr. Feistmantel's judgment is authoritative; but he has gone hopelessly astray in dealing with the geological elements of the question.

The two first parts of the Manual of the Geology of India, issued in 1879, have been out of print for some time, and the question of rewriting it has been much upon my mind. Parts of it would require abridgment, leaving local information to be sought for in the special Memoirs; and parts of it would need alteration and addition in view of extended information. The greater part of the two volumes was written by Mr. Blanford, who was for the time relieved of other work. To rewrite

the whole while carrying on the manifold current duties of the Survey has been more than I could attempt in India with any justice to either.

Museum.—The Geological Museum is in excellent order. Some valuable specimens of minerals were presented, Canadian specimens by Sir William Dawson, and English specimens by the British Museum. A good specimen of a meteorite that fell in South Arcot was sent in by the Collector of the district; a large portion of it was forwarded to the British Museum, also a good specimen to the Madras Museum. Mr. Mallet reports very favourably of the work done by Mr. Blyth as museum and laboratory Assistant.

Library.—The library is in good order. There were 2,199 volumes or parts of volumes added during the year; 1,470 by presentation or exchange, and 729 by purchase. I would here gratefully acknowledge the to me invaluable service rendered this year, as always, by Mr. W. R. Bion, as Librarian and Registrar, in charge of the office. Without an efficient and thoroughly trustworthy officer in this post, there would be endless inturruption and anxiety for the Head of the Department.

The employment of Natives as geologists.—For the last 15 years this has been a burning question for the Geological Survey of India, and as for almost the whole period the opposition to the proposal has fallen upon me, whether as officiating or permanent Head of the Department, I wish to explain overtly, especially to the natives themselves, the reasons that have guided me, though I can only do so very briefly. I would first indicate the speciality of the case in the general question of Government employment as due to natives—a principle which I entirely accept, if limited by reason: this small Department is a mere drop in the ocean of employments under Government, and the field-duties involve no intercourse with the inhabitants—the geologist goes about with map hammer and compass and need interfere with no one. These are collateral (administrative) reasons against any urgency for such appointments, if the special reasons against them are strong. The difficulty on this latter side is to get people even to understand the reasons, whether technical or intrinsic; and men in power are very loth to admit that there is anything they cannot grasp.

The special reasons then are, that the Survey has no duties of a mechanical nature, to which and through which it would be possible to break-in the uninitiated; that the facts it has to deal with are not facts in the usual meaning, as immediately appreciable by the senses,—mankind was for long familiar with stones before the geologist arose to put meaning into them; the facts he deals with are imputed to the stones by the interpretation of their characters as visible and tangible, through the knowledge of the various agencies of nature as studied in the physical sciences. The geologist's work is therefore sound and useful or false and misleading in proportion to his real acquaintance with the actuals and the principles of the exact sciences, and unless he reaches a certain standard of excellence his work is absolutely useless, or worse. In this respect the geologist is unique. A doctor may acquire a useful skill in the practice of medicine without being anything of a biologist; an engineer may do fair work with little or no knowledge of mechanics; a man may be a surveyor (of the earth or sky) without any proper knowledge of geodesy or astronomy; because in all these businesses there are practical rules by which ordinary work can be safely executed, and there would be no sufficient reason for excluding natives

on the ground of their ineptitude for original scientific work. Geology is the opposite of all this: there is no operation called for; every act in its service is an independent judgment upon very complex inductive facts through an accurate knowledge of physical phenomena and their laws; if not scientific it is nonsense. Further it is to be noted that the data upon which the geologist has to frame his judgments are for the most part very scanty: from occasional scattered sections or single outcrops he has to attempt the representation of the rocks as they lie underground and of their remote history. Thus, though based on the exact, it is itself the most inexact of sciences, and eminently demands conscientious and sober judgment. There is no science with which it is so easy to acquire a superficial acquaintance and to play the impostor. It is therefore evident that though eminently suited as an element of primary education, to open the mind of the young to the interpretation of nature, geology is eminently unfit as an introduction to scientific work, even for those in whom the aptitude may be presumed, much more unfit for natives with whom no such presumption is apparent, and in whom the disqualifying proclivities are very pronounced, especially in Bengalis.

I might leave the matter in this sufficiently presumptive state, but my chief object would be missed—to bring the native (and especially the Bengali, as the one most in error) to reflect upon himself a little. The impostor, in the most objectionable sense of the word, only deceives others; whereas the Bengali deceives himself. He seems fully convinced that with but a little more teaching he could take the lead in everything. In the question under notice, that of science, this opinion betrays a quite stupendous failure of the missing inductive faculty. What are the facts? A large number of the chiefs in the annals of science in Europe did not have a tithe (if any at all) of such scientific teaching as has been thrown away upon the Bengali youth for the last 50 years; they were self-taught men. In most considerable towns of England there are societies of workers in science. From how many a village of England and Scotland have we not heard of poor men —cobblers, journeymen tailors, masons, &c.—who have half starved themselves in the pursuit of some scientific object? In all, the mental germ was there, and it grew in spite of every want and obstruction. In Bengal the word of knowledge has been preached for the last two generations, but *in no single case* has it found the needful germ in which it might come to maturity and bear fruit in original scientific work; it seems only to develop a more obnoxious kind of weed, words of science without substance. In the medical and engineering services they have for long had like teaching and opportunities to those from which Darwin, Huxley, Tyndall and a host of others have arisen, but of like result in Bengal there is no symptom even. For a still longer period the practical results of the new knowledge in the shape of material progress have been displayed with ever increasing energy from the West, but neither has this awakened in the oriental mind a power to do likewise. Of imitation there is no lack, but of creative power there is no sign. If this is not a demonstration on the part of the Bengali of his ineptitude for science—that the presumption aforesaid is a hard fact—evidence counts for nothing. He would do well to take it to heart, if by any means he may correct his failing. Meanwhile, even if there were not particular evidence to confirm it, I hold this as sufficient warrant for objecting to the appointment of natives to the slender staff of the Geological Survey.

It would be wrong not to offer any elucidation that suggests itself of so prevalent and mischievous a delusion; for there are not a few very able men who more or less share the Bengali's persuasion of his own intelligence, and I am not at all concerned to dispute their position, because in fact, whatever their mental potentiality may be, their learning is in kind very much on a par with his, and in dialectical skill he may be quite their equal; so they are as incredulous as himself that he should not be able to master such a simple thing as geology. The question cannot, in truth, be argued as one of degrees of intelligence; it is essentially a specific difference. If there is anything new under the sun it is positive knowledge; and it is no less marked as a modern characteristic of the Western man. This is simply another way of stating the facts already set forth. Whether the difference is temporary or not is a question for the future. All manner of biological and psychological complexities might be involved in discussing the question; I will only give a superficial indication of the contrast suggested between learning and knowledge; it is an appropriation of the admirable distinction drawn by Dr. Newman in the Grammar of Assent between 'real' and 'notional' apprehension, as the characteristic difference between efficient and non-efficient faith, or rather between faith and profession. In the former there is such a vivid conception of the dogma as real, that the subject has no power but to obey; while in the latter, profession is merely intellectual in the most superficial sense. Dr. Newman's application of the distinction is actual enough, but obviously artificial and delusive; the conviction (faith) thus wrought by persistent imagination would be just as real and just as good evidence for dogma in the case of the Indian jogi as of the Christian martyr. In our present contention the terms are beautifully applicable: positive knowledge may be taken up by a real or a notional apprehension; the former is only attainable as a direct revelation of nature herself to the earnest student, in whom faith in nature is the needful germ; from this indeed there springs a conviction which need no longer be called faith, it is knowledge, the only 'real apprehension.' With it will expand the faith from which it sprung, until together they cleanse the earth and man. But of course the formulæ of science can be acquired and dealt with notionally, like any other barren knowledge or learning; and for this kind of accomplishment the Bengali has quite a special genius. Perhaps the needful germ of faith in nature has not yet descended to him; he only believes in the dictionary.

Personnel.—Mr. Mallet was absent on medical certificate from the 30th of April to the 25th of November, Mr. Jones officiating for him as Curator. Mr. Hughes was absent on furlough from the 20th of May to the 25th of November. Mr. Fedden returned from furlough on the 9th of November. Mr. Jones has been transferred to Upper Burma during the current season.

I am glad to be able to announce that Dr. Fritz Nœtling has been appointed by the Secretary of State as Palæontologist to the Survey, in succession to Dr. Feistmantel.

This being the last opportunity I shall enjoy of writing the annual Administration Report of the Department, I take the occasion to bid farewell to my colleagues, wishing that they may find as much pleasure as I have found in the performance of our work.

CALCUTTA, H. B. MEDLICOTT,
The 31st January 1887. *Director of the Geological Survey of India.*

List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India, during the year 1886.

BALLAARAT.—School of Mines.
BALTIMORE.—Johns Hopkins University.
BASEL.—Natural History Society.
BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
" Royal Prussian Academy of Science.
BOMBAY.—Bombay Branch, Royal Asiatic Society.
" Natural History Society.
BOSTON.—American Academy of Arts and Sciences.
" Society of Natural History.
BRESLAW.—Silesian Society.
BRISBANE.—Queensland Branch, Geographical Society of Australasia.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Royal Geographical Society of Belgium.
" Royal Malacological Society of Belgium.
" Royal Natural History Museum of Belgium.
BUCHAREST.—Geological Bureau.
BUDAPEST.—Hungarian National Museum.
" Royal Geological Institute, Hungary.
BUENOS AIRES.—National Academy of Sciences, Cordoba.
BUFFALO.—Society of Natural Sciences.
CALCUTTA.—Agricultural and Horticultural Society.
" Asiatic Society of Bengal.
" Editor, Indian Engineer.
" Indian Museum.
" Meteorological Department, Government of India.
" Survey of India.
" The Calcutta University.
CAMBRIDGE.—Philosophical Society.
CAMBRIDGE MASS.—Museum of Comparative Zoology.
CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Royal Danish Academy.
DEHRA DUN.—Great Trigonometrical Survey.
DELFT.—Polytechnic School.
DIJON.—Academy of Science and Arts.
DRESDEN.—Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
" Royal Dublin Society.

DUBLIN.—Royal Irish Academy.
„ Science and Art Museum.
EDINBURGH.—Royal Scottish Society of Arts.
„ Scottish Geographical Society.
GENEVA.—Physical and Natural History Society.
GLASGOW.—Glasgow University.
„ Philosophical Society.
HAMILTON, CANADA.—The Hamilton Association.
HARRISBURG.—Second Geological Survey of Pennsylvania.
HOBART.—Royal Society of Tasmania.
KÖNIGSBERG.—Physikalisch-Okonomische Gesellschaft.
LAUSANNE.—Vaudois Society of Natural Sciences.
LIÉGE.—Geological Society of Belgium.
LISBON.—Geological Survey of Portugal.
LONDON.—British Museum.
„ Geological Society.
„ Iron and Steel Institute.
„ Linnean Society.
„ Royal Asiatic Society of Great Britain and Ireland.
„ Royal Geographical Society.
„ Royal Institute of Great Britain.
„ Royal Society.
„ Society of Arts.
„ Zoological Society.
MADRID.—Geographical Society.
„ Royal Academy of Sciences.
MANCHESTER.—Geological Society.
„ Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria.
„ Geological Society of Australasia.
MILAN.—Royal Institute of Science, Lombardy.
„ Society of Natural Science.
MONTREAL.—Geological and Natural History Survey of Canada.
„ Royal Society of Canada.
MOSCOW.—Imperial Society of Naturalists.
NAPLES.—Academy of Science.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—The Editors of the "American Journal of Science."
PARIS.—Geograpical Society.
„ Geological Society of France.
„ Mining Department.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.

PISA.—Society of Natural Sciences, Tuscany.
ROME.—Royal Geological Commission of Italy.
„ Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
ST. PETERSBURG.—Geological Commission of the Russian Empire.
„ Imperial Academy of Sciences.
SALEM MASS.—American Association for the Advancement of Science.
„ Essex Institute.
„ Peabody Academy.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
STRASBURG.—Royal University.
SYDNEY.—Australian Museum.
„ Department of Mines, New South Wales.
„ Linnean Society of New South Wales.
„ Technological, Industrial and Sanitary Museum.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VENICE.—Royal Institute of Science.
VIENNA.—Imperial Academy of Sciences.
„ Imperial Geological Institute.
„ Imperial Natural History Museum.
WASHINGTON.—National Academy of Sciences.
„ Philosophical Society.
„ Smithsonian Institution.
„ United States Geological Survey.
WELLINGTON.—Geological Survey of New Zealand.
„ New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ German Naturalists' Society.
„ Seismological Society.
YORK.—Yorkshire Philosophical Society.

The Secretary of State for India.
The Governments of Bengal, Bombay, Madras, North-Western Provinces and Oudh, and the Punjab.
Chief Commissioners of Assam and Burma.
The Commissioner of Northern India Salt Revenue.
The Resident at Hyderabad.
Foreign, Home, and Revenue and Agriculture Departments.

Field-notes *from* Afghánistán: (*No. 4*)—*from* Túrkistán *to* India, *by* C. L. GRIESBACH.

Introduction.—The return march of the Afghán Boundary Commission to India, over the Hindu Kúsh and through Kabul, completed my geological reconnaissance of Afghánistán, and it has in a certain degree connected my work with that of my colleagues on the north-western frontier of India.

As I have had nearly always to conform closely to the movements and march of the Commission, opportunities for geological observations were naturally extremely limited, but my chief regret in connection therewith is, that I could not devote more time to the country lying north of the Hindu Kúsh.

I received permission to march to Charikár in advance of the Mission head-quarters, which moved two days behind me. I therefore left the Tangi Shadián (south-east of Balkh) on the 18th September 1886, and marched through Tashkhurghan and Haibak to Ghori, which is one of the districts of Badakhshán. Thence I went over the Chahárdar pass to Siáh Gird, from where I made an excursion to Farinjal. From Búrj-i-Gúl-Ján I was recalled to meet H. B. M.'s Commissioner at Siáh Gird. The remainder of the march to India brought us through Charikár and Kabul by the Khaibar route to Peshawar, where we arrived on the 1st November, having altogether been absent from India two years and two months.

Physical Geography.—Regarding the geographical features of the country north of the Hindu Kúsh which I traversed on this return march, there is little to say in addition to the description given in my last paper of the area between Bamián and Tashkhurghan.

Between Haibak and the Chahárdar pass I crossed the south-west corner of Badakhshán, the general physical characters of which may be said to be a continuation of the country between Haibak and the main watershed. It is drained by the headwaters and affluents of the Kundúz and Aksarai rivers; the latter in its upper course being known as the Súrkh Rúd. I had to cross its main branch near Dahána Iskár, where I found it a considerable volume of water, flowing in a deep valley of erosion. Numerous smaller streams drain from the main range of the Hindu Kúsh into the Súrkh Rúd, and most of these deep branch-valleys form routes to and over the Hindu Kúsh into the valley of the Ghorband river, which with its many branches forms one of the headwaters of the Kabul river.

Orographical and geotectonic features.—The outline description which I have given of the ranges between Bamián and the Túrkistán plain in my former report, equally applies to the entire section between India and the Oxus, as far as regards the general character and origin of the hill ranges. That is to say, it is a more or less continous succession of anticlinals between Attock on the Indus and the plains of Túrkistán, arranged in lines running more or less from west to east. These are accompanied by outbursts of igneous rocks along far stretching fissures of probably post-cretaceous age amongst which syenitic granite and traps are most conspicuous.

The lines of fissure correspond generally with the direction of the anticlinals, although at several points the reverse is clearly seen. Whether the latter case holds

good in the ranges which form the system of the north-east Hindu Kúsh and the ranges of Kafiristán I cannot say, but think it is probable.

Intrusions along lines of fissures, some of them on a very large scale, are seen in the Hindu Kúsh range, the Paghmán hills, the hills around Kabul and east of that city where they form the eastern Lataband and many of the minor ranges on the route to India.

Anticlinals of the Kara Koh and Karmard.—The high anticlinals of the Kara Koh and the Karmard neighbourhood flatten out considerably as they strike eastwards, forming wide depressed table lands between the lines of folds. Such for instance are the flats south-east of Haibak and Ghori, which are divided by widely arched anticlinals. South of Ghori the cretaceous rocks, which form the main mass of the country, rise again into a series of wide arches, which are eventually lost or at least very much obscured by the eruptive rocks of the Hindu Kúsh. The Zindjitak Kotal for instance leads over one of these wide anticlinals, the southern flank of which is denuded by the system of the Súrkh Rúd. The Hindu Kúsh is formed probably by a system of parallel flexures, which result in a series of separate ranges as it were, but the structure is greatly obscured by intrusive igneous rocks, chiefly hornblendic granite, which has altered the neighbouring formations into metamorphic-schists. The main mass of the Hindu Kúsh is a mighty chain with elevations of from 14 to 16,000 feet even in its south-western portion, and it bears distinct traces of having undergone extensive glaciation in recent geological times.

The eastern half of my last section in Afghánistán belongs to the drainage of the Indus, by the basin of the Kabul river, which with its many affluents has deeply eroded the southern slopes of the Hindu Kúsh and the ranges south and east of it.

The country still bears the same character of great anticlinal folds forming parallel ranges, with intrusions of granite and trap which have metamorphosed the greater part of the sedimentary strata composing these ranges. Here the general strike of the intrusions is across the direction of the anticlinals, being mostly in a line from south-west to north-east, whereas the direction of the anticlinals is nearly uniformly from west to east.

Literature.—The literature relating to matters connected with the geology or mineral resources of Afghánistán is very limited, and is mostly confined to descriptions of places and districts on the frontier or of Southern Afghánistán.

The only authors which I found treating of geological matters connected with Northern Afghánistán are the following:—

P. B. LORD—Some account of a visit to the plain of Koh-i-Dámán, the mining district of Ghorband, and the pass of Hindu Kúsh, &c., Jour. As. Soc. Beng., Vol. VII, page 521.

J. PRINSEP—Report on ten specimens of coal from Capt. Burnes. Jour. As. Soc. Beng., VII, page 848.

MAJOR VICARY—On the geology of the Upper Punjab and Peshawar. Quart. Jour. Geol. Soc., VII, 1851, page 38.

DR. A. FLEMING—On the Geology of part of the Sulimán range. Quart. Jour. Geol. Soc., IX, page 346.

CAPT. HAY—Fossil shells discovered in the neighbourhood of Bajgáh, Afghánistán. Jour. As. Soc. Beng., IX, page 1126.

E. E. DRUMMOND—On the mines and mineral resources of Northern Afghánistán. Jour. As. Soc. Beng., X, page 74.

H. B. MEDLICOTT—On geological specimens from Afghánistán. Proc. As. Soc. Beng., 1880, page 3.
H. B. MEDLICOTT—On rock-salt from the Kuram valley. Proc. As. Soc. Beng., 1880, page 123.

Geology.—The geological structure of the section between Túrkistán and Peshawar is simple, in spite of the great changes which have taken place near the numerous intrusions of igneous rocks.

The prevailing rocks belong still to the upper cretaceous period, mostly in the form of hard limestones covering with a thick skin the greater part of the area traversed. Below this, where deep erosion combined with high flexure has exposed the base of the cretaceous series, some members of the older formations appear. The "red grits" and dark shales of the upper jurassics are easily recognized, and are seen at several places; but only at one spot, on the Fazák or Bazák pass north of the Chahárdar pass in the Hindu Kúsh, did I see any rock, which could be identified as older than jurassic. The rock in question is, I believe, carboniferous, and is an eastern continuation of the Palú Kotal (near Bamián) carboniferous limestone.

The greater part of the country between the Hindu Kúsh and Attock shows little more than metamorphic and igneous rocks, in which only here and there shoals, as it were, of the upper beds of the mesozoic series were left intact; and those often are highly metamorphosed.

Part of the return march to India, namely the distance from Shadián to Haibak, was over ground I had already visited and described.[1]

Description of section between Shadián and India.—Starting from Shadián, south-east of Balkh, I descended into the Bactryan plain, part of the great valley of the Oxus, now filled with tertiary and recent strata and which is in process of dividing into two separate and parallel valleys.

I have had no better opportunity this time of examining in detail the tertiary beds of Tashkhurghan. In lithological character the Tashkhurghan series is not distinguishable from the Mathar or Bamián rocks. On a base of lower tertiaries and miocene marine clays[2] rests an enormous thickness of freshwater beds, chiefly buff and reddish coloured hard clays and sandstone, plant shales and grits, belonging to one structural whole and which I include in the pliocene series.

They rest with their older tertiary base conformably on the upper cretaceous (Exogyra) limestone, and are with the latter contorted and raised up, here and there even vertically. Near Tashkhurghan the hard Exogyra limestone beds pass at an angle of about 75° to 80° under the tertiaries, the whole series being favourably exposed by the Tashkhurghan river which forms a transverse valley (one of the finest gorges in Túrkistán) through the entire series.

The road to Haibak leads along the valley of this river, which cuts transversely through the whole system of flexures. Apparently there is a wide open synclinal north of Haibak which is bounded on the north by several narrow anticlinals and sharp folds. Inside the synclinal north of Haibak some members of the tertiary

[1] Rec., Vol. XIX, page 235.

[2] Mr. Ney Elias brought specimens of Ostrea multicostata, Desh. var., from the beds of Tashkhurghan. It is a miocene species, identical with similar forms found in the Herat province and at Kilif.

system are inclosed and can easily be distinguished by their bright colouring from the underlying dark grey cretaceous limestone. They form some of the lower slopes of the left (west) side of the valley, north-west of the town of Haibak. I did not examine them closely as they were too far off the line of march.

Near Haibak, where the river flows through this synclinal, it forms a wide and very fertile valley, but further north it cuts through several high anticlinals, producing a transverse valley with precipitous sides, often only a narrow gorge, as for instance near the village of Sáyád and south of Tashkhurghan.

The geological structure is exceedingly well exposed in this gorge, particularly near Sáyád, where the beds of the Exogyra limestone are highly contorted. The lowest portion of the anticlinal is seen to be coarse red grits and brick coloured sandstones of the "red grit group" (upper jurassic or neocomian). The centre of the flexure is just south of the Tashkhurghan gorge and there the red beds dip at a steep angle below the Exogyra limestone, but I question whether I could have made out the true relation of these red grits by simply marching along the route in this gorge. At least from the base of the narrow gorge the true relations of the red grits to the cretaceous limestone are not quite clearly seen. But during our residence at Shadián last summer I observed the same anticlinal at two other points. The Shadián streams erode the cretaceous limestone down to the red grits, which are *in situ* about a mile south of the Tangi Shadián, and they underlie the cretaceous limestone conformably.

To the east of the Shadián valley and parallel with it is the basin of Már-Múl, a picturesque highland valley, surrounded by enormous and precipitous cliffs. Here also the anticlinal is clearly exposed and the red grits are seen to be well developed, forming a thick band of densely red-coloured beds near the centre of the anticlinal; they dip below the outer (northern) flank of the arch, and also disappear below the high cretaceous cliffs which form the southern margin of the Már-Múl valley. The road which leads from Már-Múl over a high kotal into the Tashkhurghan river valley (east of Már-Múl) creeps along the up turned edges of the "red grits."

The Balkh-ab also traverses the same anticlinal, and the structure of it is laid bare on the steep hillsides forming the valley through which the Balkh-ab escapes to the Túrkistán plain. I have not been on the spot itself, but a clear view of the section may be seen from the high points south and south-east of the Shadián valley. The "red grits" are also here laid bare below the overlying Exogyra limestone.

The thick group of limestone beds which rest seemingly conformably on the "red grits" at Shadián and the ground east of it, shows much the same character which distinguishes this formation in other parts of Túrkistán. It forms high precipitous cliffs, generally of a very uniform white to grey, thickly bedded limestone, which besides corals also contains Exogyra, Ostrea, Hippurites sp., Inoceramus, Terebratula, etc.

In some places the limestone is porous, soft and chalky with strings and nests of flints. The upper beds of it are a white porous limestone and shell breccia with many fossils, chiefly bivalves, amongst which a large species of Ostrea is conspicuous. I observed this upper horizon especially well developed at Kafir Kala, about 11 miles south of Shadián, and on the high ground between these points, where

it forms the gently undulating grassy downs which cap the Shadián anticlinal, and then gradually slope down to the synclinal depression south of it.

Lithologically this horizon is identical with the uppermost beds of the cretaceous series of North-West Afghánistán; the cliffs of Houz-i-Khudá, between Chakáu and Kálanáu north of Herat consist of precisely the same rock, and seem also to contain similar fossils. It is quite possible that this portion of the Exogyra limestone series will have to be included in the lower eocene. The latter seems closely connected with the upper cretaceous group in Western Persia and the Armenian frontier and a distinct division between the two formations is nowhere visible.

On the route from Tashkhurghan to Haibak the character of the cretaceous group remains the same throughout, and I believe that the entire thickness (about 2,500 feet) of limestones aud marls which composes this formation represents the upper cretaceous horizon. I could not discover any unconformity between the latter and the upper jurassic red grits which are seen to underlie the former near Sáyád, south of Tashkhurghan, at Már-Múl and places west of it. That this is not the case in all sections is well shown in the cliffs immediately south of Haibak, near the village of Doáb, where the unconformity between the red grits and the Exogyra limestone is very marked. (See Records, Vol. XIX, page 249.)

Haibak itself lies in a wide synclinal in which some few remains of tertiary beds are traceable. They form the low slopes and terraces on the left side of the valley, and are evidently conformable to the underlying cretaceous formation.

The road from Haibak to Dahána Ghori crosses two low kotals, east of the Kotal-i-Archa and a spur which separates the Chasma Shir basin from that of Dahána Ghori.

Both these kotals cross ranges which are the continuation of the anticlinals of Rui and Doáb, south of Haibak. Between each of them extend wide synclinal troughs, which even become depressed tablelands with nearly horizontal bedding. The latter is well seen between Haibak and the Kotal on the road to Robát. I believe some of the lower cretaceous marls crop up below the Exogyra limestone; the lithological character is precisely identical with the white Baculite marls of Zulfikár and Zorabád. None of the jurassic or older formations crop up along this route.

Near Robát, on the road to Dahána Ghori, and between the latter place and the Kotal-i-Zinjiták trap dykes, with bosses and strips of syenitic granite traverse the cretaceous limestone. Towards the Kotal-i-Zinjiták the number of these intrusions increases rapidly and they widen in extent. The direction of the dykes runs more or less parallel with the strike of the anticlinals, and south of the Zinjiták Kotal the only prevailing rocks are of igneous nature. One enters there a broad belt of intrusive rocks with some inclusions of semi-metamorphic strata, forming the main range of the Hindu Kúsh between the Súrkh-Rúd and the Ghorband valley.

The same formation of more or less altered strata with intrusions of granite and traps is seen from the south-western corner of Badakhshán to Attock on the Indus. I believe it is possible, however, to distinguish the main divisions of groups in spite of the alteration which has taken place near the contact with the igneous rocks.

How clearly defined the boundary of the igneous belt with the cretaceous limestone is, may be seen from the heights above the Dahána Iskár or from the Kotal-i-

Fazák (elevation above sea-level 10,000 feet), south of the former. Looking back on to the country lying northwards, the dark traps and granitic rocks contrast strongly with the light coloured limestones of the cretaceous formation. The igneous intrusions form quite a network of dark lines near the boundary of the cretaceous limestone, and this can be seen to extend far away east and westwards of the Zinjiták Kotal. The boundary runs almost due west and east.

From that point to the Indian frontier there is very little change in the geological structure. The most prominent amongst the igneous rocks of the Hindu Kúsh belt is a syenitic granite, apparently of the same lithological character, and belonging to the same mass of intrusion as the granite of the Northern Ak Robát Kotal, south of Saighán. I found the syenitic granite in great force as a wide belt between Chahárdar camping ground and the top of the Chahárdar pass 14,100 feet, which leads over the Hindu Kúsh. The trend of this belt of granite is almost due west to east and seems to compose the greater part of the Hindu Kúsh range. Besides this the entire region between the Súrkh Rúd and the top of the Chahárdar pass is traversed by numerous granite veins and dykes. The entire series of sedimentary beds which occupy the ground between the granite intrusions has been completely altered by the latter, and has been converted into a succession of metamorphic strata. The prevailing rock is a gneiss with mica schists, but dark coloured phyllites with enclosed indurated limestone are also common. Near Sar-i-Iskár great trap masses have intruded in the syenitic granite and are found as dykes throughout the mass of hills, over which the Kotal-i-Fazák leads. The top of the latter shows a few fragments or shoals of hard grey limestone, locally converted into a sugar-grained white marble, which I believe (on purely lithological grounds only) to be cretaceous. In that case I may perhaps look upon the metamorphic beds immediately underlying the white marble as representing the "red grits" and the plant-bearing series. Below this section of the metamorphic series, on the south slope of the Kotal-i-Fazák, I noticed some beds of very hard splintery, dark limestone, which underlies the metamorphic, subcretaceous series comformably. In it some sections of shells (brachiopods) are visible, and sections of encrinites are not uncommom. It would be difficult to assign any definite age to this limestone, but the lithological character of it is very similar to that of the carboniferous limestone of the Palú Kotal near Bamián, whilst its geographical position in the strike of the latter would point to the possibility of the palæozoic series also being represented in the Hindu Kúsh.

Between this point and the Koh-i-Dáman near Chárikár the Hindu Kúsh is seen to be formed by a succession of anticlinal folds, traversed by igneous rocks, amongst which syenitic granite is again very conspicuous. As the whole complex of sedimentary strata is entirely changed by contact with these intrusive rocks, any correlation with the sedimentary groups of Túrkistán must be very uncertain.

As I have shown, the section of the Fazák pass may represent the whole series from the carboniferous to the cretaceous formation. The lowest and highest beds of the series at least have some lithological characters in common with these two formations.

Immediately south of the Fazák Kotal, near the camping ground of Chahárdar great masses of intrusive hornblende granite appear and south of it nothing else is seen but various varieties of the same rock until the top of the Chahárdar pass

(14,100 feet) is reached where a few shoals of limestone are enclosed in the granite and have been converted into a fine-grained white marble. South of the pass, on the slopes of the Hindu Kúsh which lead down to the Ghorband valley, large masses, some showing traces of the original structure, of light grey limestone rest seemingly conformably on a series of semi-metamorphic rocks, closely resembling in litho logical character the series of the Fazák pass. In the gorge of the Ghorband river between Búrj-i-Gúl Ján and Charikár I also noticed several thin seams of impure graphite in beds of micaceous schist, which resemble the altered beds and graphite seams of the section between Ak Robát and Saighán.

If my supposition is correct that these beds are identical with the Fazák Kotal series and also with the Palú and Ak Robát Kotal section, then it would appear that the carboniferous and supra-carboniferous beds of Saighán strike across the Hindu Kúsh, and form a wide belt of greatly crumpled strata, which have been traversed and intruded by igneous rocks, amongst which the most conspicuous is a hornblendic granite. The belt of the latter, which is only of narrow width north of the Ak Robát Kotal near Saighán, widens out so tremendously that the entire main range of the Hindu Kúsh where I crossed it seems formed of it. It appears therefore that the belt thins out westwards; and in all probability it will be found that in the valley of the Upper Balkh-áb (Rúd-i-Band-i-Amir) a carboniferous section will be found, free from disturbing granite intrusions.

On both sides of the Hindu Kúsh there are also cretaceous rocks (limestones) resting on the older and altered strata; here I could not detect an uncomformity, which is very plainly seen in the Bamián Haibak sections.

The remaining distance from Charikár to Peshawar was done by long marches and along a made road, which offered few good opportunities of making geological observations. The valley and basin of Kabul itself is chiefly composed of igneous rocks (hornblendic granite and traps) with some few portions of altered strata, which crop up at a few places near the margin of the valley, and which form the ranges of the Takt-i-Sháh, the Sher Darwaza, the range west and north of the Kabul lake, &c. The valley is filled up by recent and sub-recent formations which form the rich soil for which Kabul has been famous since the earliest times.

Far to the east and north-east, light grey precipitous cliffs are seen to overlie the dark igneous and altered series of Kabul, and I believe I may not be far wrong in identifying these light coloured cliffs with the upper cretaceous, which plays such an important role in the structure of Afghánistán.

The hills of Bútkhák, through which the Kabul river has formed a narrow gorge, the Tangi Gháru, consist of the well-known red grit group with overlying cretaceous limestone of typical character. The section dips east, but I found that the Lataband and the hills eastwards are formed by a succession of anticlinal flexures, some of them exceedingly perfect. The road from Bútkhák over the Lataband pass to Seh-i-Bába leads over a succession of low spurs of altered cretaceous limestone and igneous rocks associated with the latter. The rock *in situ* on each side of the valley at Seh-i-Bába I found to be a dark trap with veins and masses of light green serpentine.

Some of the lower spurs on that route are hidden under thick deposits of sub-recent gravels and reddish clays, which form high level terraces in the Kabul river basin. The road from Seh-i-Bába to the head of the Pari Darra, past Jagdallak

fort and over the Jagdallak pass, leads over the same series of altered strata. Near Jagdallak it is a gneissose schist, highly contorted. Further on the road skirts this formation, passing over a succession of low kotals and undulating ground (Pezwán Kotal, 44th hill, &c.) down to the Gandamak plain.

The greater part of the ground so traversed is composed of sub-recent and possibly pliocene formations. The uppermost portion of them is composed of conglomerates and fine reddish grey sandy clay, very like the aerial (loess) formations of the Chúll. The lower beds, which nearly everywhere show a decided south-east dip, are chiefly composed of soft grey (pepper and salt) sandstones and flaggy sandstone-shales with conglomerates. These deposits bear a strong resemblance to the Manchhars and Upper Siwaliks and are quite distinct from the conglomerates and sands, which are discordantly reposing on them.

Between Gandamak and Rozabád the road crosses a series of low spurs all running more or less north or north-east; they are all composed of soft sandstones and conglomerates (Upper Siwaliks) with a rolling dip to the east and are overlaid by horizontally bedded loess and conglomerates of recent origin. The latter forms wide gravelly terraces or low plateaux, ending in steep scarps.

East of Rozabád, the higher ranges come close up to the river, and consist there of altered strata, highly contorted, grey gneissose schists, and intrusions of trap and serpentine, which form quite a network of dykes and veins in the crystalline schists. The same formations are seen to be *in situ* on the opposite side of the Súrkh-áb, in the Siáh-Koh range. The valley widens out to extensive and very fertile alluvial plains near Jalalabád and Chahárdeh. The road skirts the more or less solated ranges east of Ali Boghán and the hills of Basawal. They consist of altered strata and schists with trap intrusions, and are part of the Siáh-Koh structurally.

The same remarks apply to the spurs which are crossed between Basawal and Dakka on the south side (right bank) of the Kabul river.

Near Haft Cháh, the road enters the narrow valley which leads to the Lundi-Kotal. The prevailing rock is altered limestone (cretaceous?) and schist, amongst the latter a fine-grained grey gneiss with mica schist and greenish grey phyllites. No change of rock is perceptible, excepting that some of the grey limestone near the west entrance into the Khaibar pass seems less altered and closely resembles the upper cretaceous limestone of Afghánistán. Similar rock is seen near the eastern (Indian) entrance into the Khaibar. I have looked in vain for fossils in any of the rocks. The Khaibar limestone, however, is undoubtedly part of the same limestone formation which forms the Kohat pass and Afridi hills south of the Peshawar plain, which are cretaceous and are overlaid conformably by the nummulitic limestone of the Kohat District.

Notes made during the last war in Afghánistán.—As will be seen from these notes on the country between Kabul and Jamrúd, the section is not a very favourable one; fortunately we possess a few stray notes on the neighbouring areas, collected during the progress of the last war which afford a slight aid in interpreting the structure of this part of Afghánistán.

From specimens[1] which were brought during the last war from Northern Afghán-

[1] H. B. Medlicott, Proc. As. Soc. Beng, 1880, p. 3.

istán, it appears that the north side of the Sikaram in the Saféd Koh range is composed of transition rocks, amongst which magnesian and calcareous beds predominate.

From the western flank of the same hill and from an elevation of about 10,000 feet, Dr. Aitchison brought specimens of unaltered shales with fucoid markings. A similar rock is *in situ* on the south side of the peak. From the Shalinar stream, east side of the Paiwar Kotal, a pebble of Lithodendron limestone was brought. The latter is possibly of carboniferous age. It would appear then that beds of palæozoic age accompanied possibly by older mesozoic strata exist in the Saféd Koh range and form the highest part of it. Pebbles of palæozoic rocks, probably of carboniferous age, have been found by Major N. Vicary [1] near the Khaibar mouth near Jamrúd and both the locality last named and the Sikaram beds seem to belong to one belt of palæozoic strata, of which the Attock section is the eastern continuation.

The group of altered rocks between Jagdallak, Gandamak, and Ali Boghán may be outliers of the same formation.

Glacial. Recent formations.—In my former paper,[2] I had occasion to mention some of the deposits and traces of former glaciers in Afghán-Túrkistán. Since then I have seen by far the most perfect instances of recent glacial action, when crossing the Hindu Kúsh by the Chahárdar pass in October 1886. The road which leads from Chápdarra camping ground on the north side of the Hindu Kúsh to the top of the pass ascends a narrow straight valley, bounded on each side by steep cliffs, some of them crowned with perpetual snow. The bottom of the valley itself is greatly choked and partially filled with debris, which might be simply the detritus from the hillsides. Large cones and fans of fragmentary material descend from each small ravine on both sides. So far only the configuration of the valley, its nearly straight course and absence of larger side streams, would suggest the former presence of glaciers. But on reaching an elevation of 12,000 feet, one suddenly comes to a huge mass of debris, which closely resembles the recent accumulations near the lower end of a glacier. Large blocks, some of them of immense dimensions, are loosely mingled with angular fragments of every size and the whole is arranged like a dam across the valley. The hillsides (gneiss) are polished and grooved and the blackened surfaces glisten and shine in the distance like metal. All the larger blocks show extensive grooving and deep ice-scratches on their polished sides. This mass of debris lies at the base of a terrace filling the valley. The former glacier, of which this is the end moraine, was on the upper and raised portion of the valley. The latter bears the remarkable appearance of an ice-worn trough; it is wider than the valley below, and its base is now partially filled by finer debris, through which a small stream winds its way amidst a series of swampy pools. It is within the area of perpetual snow and the latter with frozen patches of ice lies on the hillsides and in sheltered depressions.

The valley looks as if the glacier had only quite recently left it. Moraines and glacial silt still lie as they were deposited. The head and catchment area of the valley close to the top of the pass (14,100 feet) is still rather thickly covered with frozen snow.

[1] On the Geology of the Upper Punjab and Peshawar, Quart. Journ. Geol. Soc., VII, p. 38.
[2] Rec., Vol. XIX, p. 263.

Glacial traces on the south slope of the Hindu Kúsh.—The descent from the Chahárdar pass to the Deh-i-Tang lies down a narrow valley of much the same character as the one just described. But the most interesting feature in connection with it is, that in this valley there are some small glaciers still remaining. Near the head of the valley, just south of the Chahárdar pass, at an elevation of 12,050 feet above sea-level, several small side ravines join; I noticed three of them were still filled with glaciers, and though they were very small, the moraine accumulations near their lower ends were enormous. Especially the one from the right side shoots off an enormous cone of large fragments, amongst which there are some very good examples of ice-scratched blocks.

Recent conglomerates.—Both in Túrkistán and the neighbouring South-western Badakhshán deposits of recent and sub-recent conglomerates, sands and clays are largely developed. The hills which skirt the cretaceous anticlinals between Haibak and Dahána Ghori are formed by these deposits which attain there a great thickness. Similarly the valley of the Súrkh-áb is partially filled by them.

The valleys belonging to the Kabul river drainage south of the Hindu Kúsh are to a large extent lined with terraces of conglomerates, as, for instance, the wide terraces of Siáh-Gird, Chahárdeh, etc.

These conglomerate terraces form quite a feature in the landscapes of the road east of Kabul, amongst which I may mention the terraces of Gandamak and Nimlah Bagh.

I believe these accumulations belong to the same age as the Indus gravel beds, which are seen to skirt the hills the whole way from Peshawar to Sind.

In the next number of the "Records" I intend giving a geological map of Afghánistán and part of Persia with a summary of the geological structure and mineral resources of Afghánistán.

CALCUTTA, *23rd December 1886.*

Physical Geology *of* West British Garhwal; *with Notes on a Route Traverse through* Jaunsar Bawar and Tiri-Garhwal, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*

PART I.

Introduction.

In Part 2 of the Records for 1885 I described a fossiliferous zone of pre-tertiary age amongst the old mountain-building rocks whic/ form part of the Lower Himalaya of British Garhwal. Whe that preliminary notice was published I had only been working for a short time ˙˙ ˙-ˆ-t and consequently the area treated of was confined, and no generali? Since then, having spent another field season there, I

able to make some additions to our knowledge of the stratigraphy of those parts. But, inasmuch as this part of the Himalaya is divided from ground which has been already geologically surveyed in Jaunsar Bawar by a broad strip of almost completely unknown country, *viz.*, part of Tiri-Garhwal, I am still compelled to put aside for the present all definite correlation between the rock systems displayed in Jaunsar and those upon which I have now been engaged. In consequence of this I shall still adhere to the method observed in my preceding paper of naming the series, when fossils are absent, after their prevailing lithological character; trusting to time, and a wider experience, to eventually make them one with the old established Himalayan formations.

British Garhwal has been topographically surveyed on the one-inch scale, and the principal object of my first season's work there was to settle down on some part of it where the strata showed signs of falling into a natural order, and then work from that point as closely as the advantages of a large-scale map would admit.

But, before doing so, I went through Jaunsar Bawar (the next British possession west-north-west of British Garhwal) for the purpose of making myself as thoroughly acquainted as possible with that already mapped district. From its no great distance from Garhwal it was thought that it might have many points of similarity, and so give one new to Himalayan work a useful basis to go upon.

From the northern extremity of Jaunsar Bawar I rapidly crossed by Tiri through native territory until I struck my own working district at Srinagar in British Garhwal.

Before coming to the main object of this paper I shall therefore briefly set down a few somewhat disjointed notes referring to my route traverse: not because they have any intrinsic value, but because of their possible bearings on past or future work.[1]

Jaunsar Bawar.

The southern parts of Jaunsar Bawar were examined by me in some detail with especial regard to the position of the Mandhali series in its numerous unconformable appearances near Chakrata. It is not my province to describe these rocks, with the questions arising from which Mr. Oldham is now engaged, but the numerous examples about which I have notes, from their containing clear blebs of quartz, fragments of felsites and a great deal of felspar and felspathic material scattered about in the matrix, gave me the idea of a rock produced by the degradation of felsites or granitic rocks and produced perhaps during a time of intermittent volcanic activity. North of Chakrata, the high Deoban ridge up to Mandhali, and some way beyond, was wrapped in deep snow, the product of a late storm, at the time of my visit; and work was therefore curtailed in a great measure. What I saw of the Mandhalis there left no doubt in my mind as to their identity with the rocks classed as the same a little south of Chakrata.

At Tiutar (near the Tonse) I made a careful examination of the Chakrata series to the east of the Konain-Mudhaul fault,[2] in order to solve, if possible, the question of inversion, and whether the igneous rock was intrusive or inter-bedded. From

[1] To make these route observations more intelligible it may be noted that Mr. Oldham's Bawars are taken by him to be about on the horizon of the base of the infra-Krol group of the Simla section, the Mandhalis being older still, but newer than the Deoban limestone (see Vol. XVIII, p. 4).

[2] See R. D. Oldham's "Note on the Geology of Jaunsar and the Lower Himalaya." Rec. Geol Surv. India, Vol. XVI, 1883, p. 193.

the presence of what appeared to be thin ash beds, associated with the igneous rock, I at first felt sure both must be inter-bedded, but until microscopic sections are cut there is a possibility that they may turn out to be merely crushed and pressure-foliated diorites. With regard to inversion, the lie of the beds as contrasted in deep gorges, and on the neighbouring mountain spurs south-west of Tiutar, inclined me in favour of the supposition of inversion; for to the eye there seems to be a steepening of the beds in towards the mountain; but, on the other hand, the limestone which lies apparently immediately below the igneous rock is a very whitey-grey, compact, and marble-like rock, such as could have been produced by the contact metamorphism of the igneous rock. In addition, south-west of Tesar Khera, where the limestone contains some magnetic iron in small crystals, the contact of the igneous rock has in places altered the latter, so that it now lies as amorphous lumps filling lacunæ among the joints of the limestone. From these facts the limestone must be older than the igneous rock, and, if the latter is inter-bedded, their present position must be the original one, and the inversion theory cannot be maintained.

From Tiutar I rounded the north end of Jaunsar Bawar and left British territory at the head of the Khunigadh river which divides Jaunsar from Tiri-Garhwal.

From the Khunigadh pass I descended, in a south-east direction, to Porohla.

Tiri-Garhwal.

Except for a mile or so from the pass, where there were some diorites and ash (?) beds, there was nothing met with but Bawar quartzites during the whole descent. They lie dipping slightly towards the north-east and never exceeding an angle of 20°. Their colour is white, and, when

Bawars.

seen through a lens, they appear to be made up of little angular fragments of clear quartz and apparently nothing else. They form the exceedingly precipitous ridge west of Gundalho, lying between the two branches of the Kamalada river, which meet at Porohla. The steep bare walls into which they weather utterly barred my progress at a point on the map above the *l* of Gundalho; but, with their low dip towards the north-east, they appeared to continue much higher up towards the main range running parallel to the Tonse. I have no doubt that these are identical with the Bawar quartzites of Mr. Oldham. Porohla lies in a widened and flattened valley, given over to cultivation, and called the Rama Serai, lying to the north-north-east from the village along the present line of the river.

Along its bed there must be an unseen junction between the Bawar quartzites just mentioned, and another rock which is petrologically a gneiss. Unfortunately

Gneissose rock.

both it and the Bawars themselves, in this region, have so weathered at the surface that in the few exposures that I could examine in a hasty march I found no reliable junction that gave me a clue as to the nature of the boundary. This excessive weathering into a fine gravel of the separated crystals of the gneiss and the disintegrated grains of the quartzite, is probably the cause of the flat cultivated stretch of the Rama Serai, the valley of which has become in this locality choked with the products of disintegration. I had the gneiss with me, gradually emerging from its weathered covering, up to, and beyond Kumalo; but, when the position indicated on the map by the *l* in Kumalo was reached, it came to an end, and Bawar quartzite and some schists

continued up to the ridge, trending north from Saulda peak. The eastern boundary of this gneissose rock runs a little east of north to beyond Dokri, from the point just mentioned. This boundary is as difficult to unravel as the western boundary, for the uniform Bawars show but little dip, except where they rise in escarpments, or when schists come in among them, and even then the results are discordant.

With regard to the gneiss itself, its foliation planes, when visible, are roughly horizontal just as the Bawars are. It will thus be seen that stratigraphically no position can be assigned to it from the evidence before us, for it is not known whether the boundaries are natural or faulted; and, from the nearly horizontal dip found in every exposure, an average actual dip cannot be deduced. Then again, I have no evidence to bring forward as to whether the rock, provisionally named a gneiss, is by origin a gneiss or a granite. Petrologically it is identical with the rock of the Chor mountain, which has received much attention from Indian geologists. That rock, by Colonel McMahon's microscopical evidence, and by the still more convincing evidence of large and numerous included fragments of schist and quartzite found by Mr. Oldham and myself during the season's work of 1883-84, is by origin a granite; but whether the same can be said of this rock depends on how far an exact likeness between two rocks of this kind is to be deemed conclusive of their identity. At the same time, though willing myself to withhold judgment until more extensive mapping has been done, there is no doubt that the two rocks in so far as their mineral characters go *are* the same. There are the same quartz and felspar, with sometimes a predominance of the former; there are pale and black micas; and there are schorl crystals, developed here and there, and occurring abundantly in cracks and veins, just as they did in the gneissose granite of the Chor. In some places I found a decomposed greenstone, probably a dyke of diorite, in the gneissose rock.

From the east edge of the gneiss I crossed the ridge north of Saulda peak and followed a tributary of the Banale river, west of Kanal. The whole of the west side of this ridge was chiefly composed of the Bawar quartzites, showing no evidence of dip, except a general horizontality. At the summit of the pass, and on the east side, schistose beds came on, and continued until some inter-bedded diorites and dioritic ashes appeared below them. Then came more schists, and finally I struck in the stream bed a massive limestone of the Deoban type.

It will thus be seen that, on the east side of the gneiss, we have a set of outcrops inversely arranged to those of the west side. The following will illustrate this:—

WEST. Deoban Limestone.	Schists and igneous products.	Bawar quartzites.	GNEISS.	Bawar quartzites.	Schists and igneous products.	EAST. Deoban Limestone.

Now, the steep descent from the ridge into the tributary of the Banale, leaves the impression that the approximately horizontal beds to the east of the gneiss rank in order of superposition from the limestone below to the Bawar quartzite above; that is, we may assume an ascending series on that side of the gneiss from the limestone upwards. The west side of the gneiss is not so clear, but, from the undoubted identity of the quartzite with the Bawars there is the exact appearance there also of an ascending series towards the gneiss.

A seemingly absurd corollary follows from this: We appear bound to believe

in a gentle synclinal along the valley of the Kamalada, with the gneiss as the uppermost member of the series! Those readers who have followed the history of the geology of the Chor mountain will see that we have here exactly the same apparently unsolvable problem that at first proved too much for every one in the case of the Chor. It is true that we now have a partial answer in the case of that mountain, inasmuch as it is certain that its material has been in a condition of aqueo-igneous fusion sufficient to allow of its tearing off fragments of the neighbouring rocks among which it was intruded, and enclosing them in its substance, but we cannot assume the same explanation here until the same proofs in this case of included fragments, and the evidence of the microscope have been brought to bear on the question in this locality. Later on, I shall have to mention Kalogarhi mountain in British Garhwal, an isolated peak, also composed of this gneissose rock, and presenting in its neighbouring relations very much the same features. It also, at first, appears to lie in a synclinal, as a capping on the summit of the hill, and in many ways it may be looked upon as a miniature Chor. The explanation of the Kalogarhi rock rests, however, on the proved great age of the schistose strata amongst which it lies: although the schists there have the appearance of being the highest of the neighbouring formations. The proving of this involved much labour and time, neither of which could be given to the Rama Serai section on account of my rapid movements.

Deoban limestone.

Returning to the section down stream in the Banale river, we have the spur from the main ridge running towards Shishalu and dividing the upper branches of the Banale river, showing distinctly the various outcrops of the schists and the limestone as they appear to dip in towards the mountain and at a much higher angle than met with heretofore. The bed of limestone is not by any means thick, but between Shishalu and the ridge running east from Saulda peak, and between the last point and Palaita the thickness varies very much, becoming less as the outcrop is traced south by the last-named places to the Jumna. Beyond Palaita I could not see where it went to, but its line of strike from that place would carry it very well to join up with the Deoban limestone of Jaunsar near Lauri.

Shaly slates.

At Bigrar village (not marked on the map), which is half a mile above Deltu, the limestone beds have come to an end, and we come upon grey shaly slate dipping about 20° north-west. After a short thickness of these there comes beneath them a thin bed (not more than 60 feet) of a dark, micaceous, gneissose rock, finely foliated, and of very different aspect to that on the other side of the Saulda ridge. Of this, and other rocks collected during last season, I hope to make a thorough microscopical examination later on; I can now only say that the quartz is present in large quantities, showing the polysynthetic structure so common in gneiss of other parts of the Himalaya examined by Colonel McMahon.[1] No fluid or other cavities can be seen. The felspar is not so abundant as in a typical granite or gneiss, occurring in less quantity than the quartz; it is decomposed almost beyond recognition. Biotite is fairly represented, and there are a few needles of apatite. Whether the rock is an intrusion, or is metamorphosed *in situ*, is a question I cannot answer

Another gneissose rock.

[1] See Records, Vol. XVI, p. 144.

by any direct evidence. Its regular appearance bedded with the other rocks, and its lateral continuity between the stream and the ridge east of Saulda peak along the strike of the rocks, favours the idea of its being a true gneiss, and not a foliated granite; but, on the other hand, the selective metamorphism required to pick out a bed 60 feet thick and make it a gneiss without altering the surrounding rocks relatively at all, seems incredible.

Quartzites and slightly schistose slates.

Between Kanal and Goldar there come beneath this gneissose bed olive-grey quartzites, blue-grey quartzites, and finally slightly schistose slates, all dipping about north-north-west 50°. From Goldar to Jeshtar, and the ridge east of Saulda Peak I re-crossed over the same set of beds. I then descended towards Cheli; the latter part of the descent being entirely upon the slightly schistose slates, which in some cases became very micaceous and soft.

Gneissose granite.

Having crossed the Jumna at Barkot I took up the stream south-south-east from there, and for the first mile I passed over much the same kind of rocks, but not very schistose, the dip being irregular. Then came fragments of a granitic rock for about half a mile, though the nature of the country prevented any good exposures being seen. It appeared to be a rock related to the gneissose bed last described, but the foliation was not much marked. Then came rather gritty, close, blue-grey slates, dipping 60° west-south-west. On getting to the pass, about 6 miles from Barkot, which pass is north-52°-east from Bouk station, looking south into the tributary of the Bhagirati river there is still the gritty slate dipping 20° west-north-west. Beyond the pass, in an easterly direction, the ridge rises into a mass of the granitic rock, which also keeps to the higher parts of the spurs running down into the tributary of the Bhagirati river as far as a point east-south-east from Bouk station, where there is a sharp line of junction (probably a fault) running north-east between it and a massive blue-grey limestone. The lower parts of the same spurs are composed of the slaty rock, and some few gritty beds, with a general dip 30° or 40° west-north-west near the pass. The dip gradually veers round more to the west, and finally becomes south of west as Darng is approached. The limestone, which resembles the Deoban, only crosses the stream bed a little way, and is then cut off in another direction by a fault striking south-east almost in a direct line between Bouk station and Darng.

Returning to the granitic rock, the quartz in it is abundant, in large grains, and with no polysynthetic structure. Numerous strings of liquid cavities, and dust of opacite ramify through the quartz grains. The felspar is in the same condition as that of the Banale river gneiss. The mica is biotite as before, sometimes dark brown, but often quite black, and opaque in thin slices. The granitic mass in its upper parts seemed to change somewhat in nature and take on a rather more dioritic appearance. I was disposed at the time to think that it was indeed a gradual change in the minerals, but I had not time to stay and work all round the mountain. Specimens from the top of the ridge due east from Bouk station are almost certainly a diorite though the rock has not been sliced yet.

Continuing down the tributary of the Bhagirati near Gewla and Darng we find the same gritty slates and quartzites of dull grey colour dipping towards the south-south-west, at 45°.

It is near where the stream enters the Bhagirati that a change takes place, and the dull coloured slates and grits give way to a set of shivery slates of purple and green colours. These weather into a violet, or pale green powdery rock, which forms steep taluses on the river banks. There are some quartzite beds incorporated with them, and a few conglomerates near Upu (sheet 66). How this change sets in I did not observe, as the structure of the lower parts of the valley is much obscured by recent gravels extending up to a height of 300 feet or more on each side of the Bhagirati, and through which it has cut its course. The general dip is south-west or north-east, apparently rolling about a good deal, first in one direction and then in the other. The appearance of the beds, the nature of the conglomerate, their colouring, and especially the way they weather, forcibly reminded me of the beds seen on the road to Chakrata, near Kalsi, in Jaunsar. The whole of the fair valley of the Bhagirati down to Tiri, and probably beyond, is likewise composed as described, the uniformity being due to the recurrence of the same beds by repeated foldings.

Purple and green shivery states and quartzites.

At Tiri I left the Bhagirati river and turned east up the Bheting river, making as direct a line for Pauri as possible. As far as Nurni there does not seem to be any material change in the rocks, but looking north across the Bheting towards Kytiba and Kireh trigonometrical stations, a set of thick-bedded quartzites can be detected constituting the rugged sides and summits of those peaks. Half a mile or so north of Nurni and Koti, the same beds were traced by me running up from Ushunna along the ridge south-east and east towards Maniknath. In their lower part there is a limestone, dark blue, and resembling those already mentioned in this paper. It is only a hundred feet or so in thickness. A mile and a half east of Koti the junction between the slaty beds and the quartzite is seen on the pass leading over into the affluent of the Alaknanda river. Here, too, are some diorite and dioritic ash near the junction, and no limestone. There is also a change in the lower slaty series at this place; they lose the bright tints hitherto possessed and become more like the sombre tinted rocks that we had before entering the Bhagirati; that is to say, they are grey, and slightly schistose. They also have a nearly vertical dip south or south-west. On the left bank of the affluent, some distance above the road, the limestone and the quartzite were traced as far as Kunnali, but below this, on account of the dense vegetation of creepers, &c., nothing more could be seen of them. I should mention that this quartzite is of exactly the same type as the Bawars, a strong clear-grained quartzite, approximately horizontal, and apparently capping the heights and the ridges unconformably. It is evident, however, that having lost touch of the Bawars so long since, no reasonable correlation can be made in this case. The whole of the south-west side of the stream bed east of Chandabadni mountain down to Gar (Gur), is remarkable for the effect that the vertical or nearly vertical dip has had on the carving out of the hill-spurs: they are like a number of sharp pyramids rising one behind the other in very beautiful succession. The rest of the way to Jarkni on the Alaknanda is over the same kind of beds.

From Jarkni I crossed the Alaknanda, and arrived in British Garhwal, where I at once set to work to find a place suitable for commenc ing systematic mapping operations.

British Garhwal.

by any direct evidence. Its regular appearance bedded with the other rocks, and its lateral continuity between the stream and the ridge east of Saulda peak along the strike of the rocks, favours the idea of its being a true gneiss, and not a foliated granite; but, on the other hand, the selective metamorphism required to pick out a bed 60 feet thick and make it a gneiss without altering the surrounding rocks relatively at all, seems incredible.

Quartzites and slightly schistose slates.

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Table of formations (in descending order) in W. British Garhwal—contd.

TAL . . .	Mesozoic . .	*Upper Tál.*—Indigo coloured calcareous grit, usually oolitic; full of broken fossils. The rock might often be called a limestone, but it is never without the sandy basis. *Lower Tál.*—Strong sandstone of millstone-grit type; quartzites, &c., few quartzose conglomerates; a black carbonaceous shale, 1 foot thick, with plant impressions, occurs in the Sour-gadh.
MASSIVE LIMESTONE	Age unknown . .	Dark, blue-grey, fairly pure limestone; thick bedded; without fossils. It resembles either the Krol or Deoban limestone.
PURPLE SLATES AND VOLCANIC BRECCIA.	Ditto . .	Slates, bedding and cleavage coinciding, usually coloured a ruddy or inky purple, but sometimes grey. The volcanic breccia is an angular clastic rock, with no rounded fragments. The material is coarse or fine, and is made up of slates, quartzites, and limestone, with very rare fragments of igneous rocks and schists.
SCHISTOSE SERIES .	Ditto . .	Phyllites, quartzites, quartz-schists, schists, and garnetiferous schists, with intrusions of gneissose granite.

Without perplexing the reader by detailing the array of difficulties which presented themselves to me at different stages of my work, I will at once come to the main difficulty, in the right understanding of which all other minor questions are bound up.

If reference is made to the ¼ inch map, the eye will at once grasp the fact that there is a central elongated area composed of the schistose series and which may be called the "Inner formation;" whilst surrounding it on all sides is a zone of all, or some, of the formations from the nummulitics down to the purple slates and volcanic breccia. These may be called the "Outer formations," in contradistinction to the schistose series. Now the belief which is at present so rapidly gaining ground that metamorphic strata are presumably older than unmetamorphosed strata makes one at the first glance assume a strong probability in favour of the inner schistose series being of much greater age than the outer zone of formations. But no sooner has this *à priori* probability obtained a firm hold of the mind than a rude shock is given to it by the discovery that at every point round the schistose area the Outer formations appear to dip towards and under the schistose series at steep angles (50°—60° generally); whilst the schistose series itself is disposed apparently in the form of an elongated quaquaversal synclinal upon the top of the Outer formations, and culminates in a capping of gneissose rock on the summit of Kalogarhi mountain (locally known as Kalan Danda), the highest point of the neighbourhood.

In other words, the observer after a hasty examination is almost driven to the conclusion that there is an upper metamorphic series lying normally upon the comparatively unmetamorphosed zone of Outer formations (a counterpart of the opinion long held with regard to the strata of the Scotch Highlands).

But in one respect the geological structure in this part of Garhwal is unique, so far as I know. The appearance of the Outer formations underlying the schistose series is not confined to one line of country, but is equally noticeable at nearly *every point round the margin* of the Inner formation, whilst up the Huil and Rausan rivers offshoots of the Outer formations appear among the schistose series, fitting in with them more like a piece of gigantic inlaid work rather than lying as unconformable outliers upon them.

When I commenced field-work last season, I was in a complete state of uncertainty as to which way to interpret the sequence of the rocks. On the one hand, I was exceedingly loth to believe that an enormous thickness of phyllites, schistose slates, schists, and even garnetiferous schists could normally belong to an era subsequent to the deposition of the ordinary slates, limestones, and sandstones of the Outer formations; whilst, on the other hand, I was equally averse to straining what then seemed to be the plain facts of the case in order to draw up a more plausible stratigraphical table. Besides, Mr. R. D. Oldham's work in Jaunsar Bawar[1] and Mr. H. B. Medlicott's[2] at Simla had already shown the extreme probability of an upper and comparatively younger schistose series normally overlying slaty and calcareous strata; and I could not of course neglect telling evidence of this kind, although so great a span of country lay between their working grounds and mine.

I was also in a state of uncertainty with regard to the Outer formations themselves; for they by no means preserved a uniform relation to one another; so much so that my first statement that the massive limestone overlaid the Tal beds has had to be discarded and reverse positions assigned to them.

The most pressing difficulty then was that of stratigraphical succession. Although the superficial relations of certain rock-series to one another had been made tolerably clear, it was not manifest which of them was really the newer, and which the older; inasmuch as sometimes they appeared in one order of superposition, and sometimes in the inverse order. In other words, the problem before me was to unravel their order of deposition in time, from conflicting appearances, due to disturbance of the strata; for, in a region of true mountains, it is not enough to see one set of beds dipping beneath another set; but in every case the question must be put—is this the normal order, or is it an inverted order?

The presence, or absence of fossils, makes all the difference in the ease with which such a question is answered; though a single fossiliferous series is not sufficient by itself. But when two or more definite fossil horizons are fixed, among a set of formations roughly coinciding in dip; the sequence in time, evinced by those horizons, will necessarily proclaim the true time sequence of the whole.

Applying this principle to the comprehension of the problems before us, it was imperative to find out how the presence of the two distinct fossil horizons of the nummulitics, and the mesozoic Tal beds, in a region where the other formations are unfossiliferous, would help in settling the true order of those associated unfossiliferous rocks: whilst it was extremely probable that if the Outer formations were once chronologically arranged, a clue would be obtained which would fix the age of the schistose series. Until recently, the unfossiliferous formations had not been met with in such fortuitous conjunction with the fossil-bearing series as to enable me to

[1] Rec. G. S. I., Vol. XVI, 1883.   [2] Mem. G. S. I., Vol. III, 1863.

rightly deduce their true stratigraphical order, but the time has now come when I can speak with certainty on this point, and I can throw the whole of the strata of Western British Garhwal into comprehensive groups, arranged in true historical succession (see table of formations).

Within the confines of this paper I shall merely endeavour to show how I have arrived at my conclusions, by reference to the geology represented by the accompanying maps and sections.

Referring to the 1-inch map, it will be seen that within the general curve made by the Ganges there are a set of boundaries, marked as faults, each roughly parallel to one of the reaches of the river, and, in result, giving a compound boundary somewhat resembling the course of the river. Within this boundary, except for a narrow band up the Huil river, the rocks composing the Inner formation agree in being very compact purplish quartzites, without much granular structure visible; glossy-surfaced slates, generally slightly purplish, or considerably metamorphosed into schistose slate, and schists. On the other hand, outside the boundary there are fairly regular groupings of the Outer formations, *viz.*, the nummulitics, the Tal (mesozoic), the unfossiliferous, massive, blue-grey limestone and the purple slates and volcanic breccia.

The first point to which I would call attention is that the order of superposition (whether a true order or not) of the Outer formations, up the Ganges valley, is from the purple slates and ashes below, up through the massive limestone and the Tal to the nummulitics, which are brought to a check by the boundary (see sections AA, BB). Now, in order to discover whether this order is a normal or inverted order, we must reason in this way. The nummulitics being by their fossil contents of later age than the Tal beds, which are mesozoic in age, it follows that the apparent position of the latter, dipping underneath the former, represents the true original sequence in which they were deposited. That being so, the dip of the massive limestone beneath the Tal beds must also be an original true dip; and likewise that of the purple slates and ashes beneath the limestone.

Thus, the present arrangement of the group of Outer formations, as seen near the bend of the Ganges at Lachman-jula, from the purple slates and ashes up to the nummulitics, must be the original historical one; and so part of the previous difficulty is solved once for all.

Coming now to the nature of the boundary between the Outer and Inner formations, and the question of their relative positions: it is certainly, at first sight, a most astounding coincidence that the Outer formations in nearly every locality should persistently dip towards the presumably older schistose series; especially when we have just learnt that the Outer formations, among themselves, are in a natural order. This occurrence, so marked in many places, and the lie of the Outer formations completely encircling the schistose area, make it difficult to get rid of the first impression already alluded to that the whole is a synclinal trough, with the Outer formations below, and the Inner above. One seems almost driven to conclude that if a boring were sunk through the centre of the schistose area, we should inevitably strike the Tal beds below. The very often curved direction taken by the boundary between the Outer and Inner formations, whereby it wanders irregularly, sometimes even V-ing inwards with the inequalities of hill and valley after the man-

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But if we now enquire as to what sort of faults would be produced, we shall be obliged to own that only such as could enable the strata to take up less horizontal space, in compliance with the lateral pressure, would be of any service in relieving the state of strain. From this we see that a vertical fault, having no effect of this kind, would be of rare occurrence. On the other hand, a reversed strike-fault, inclined at some angle with the vertical, would not only relieve the constant strain and bending of the rocks, but would directly contribute to the horizontal compression of the region by allowing the rocks on one side to work up over those on the other side; thus increasing the vertical thickness of the earth's crust at the expense of its horizontal extension. There being such a manifest relief accruing from such faults as these, it is but natural to suppose there would be a strong tendency to their formation. But their direct consequence is to bring about stratigraphical complexities of precisely the kind we have to deal with, by forcing older beds over the top of younger formations. On the other hand, a fault with the down throw towards the hade would obviously increase the horizontal extension of the rocks, and there could be no predominating tendency to its formation in a tract of country subject to great lateral compression. It seems, indeed, impossible to imagine them occurring in any mountainous tract, other than some few mountains due to great vertical elevation; except as dip-faults, or as secondary results due to local and intermittent relaxations.

There is thus a good *à priori* reason for expecting to find reversed strike faults, and them alone on a large scale, in the district under discussion. But that the boundary of the Tal beds with the schistose series should be so persistently a reversed fault on the dip side, an uninjured synclinal of the younger rocks scarcely ever (in only one instance that I know of) being preserved, does seem a little remarkable, until we remember that the Tal beds, save for the slight capping of nummulitics, must have been the uppermost rocks at the time when the elevation consequent on the lateral pressure began, and therefore it would only be in very favourable conditions that any trace of them would survive from the rapid denudation consequent on emergence from the sea and subsequent atmospheric waste. Simple folding would no doubt tend to bring this preservation about by allowing the anticlinal folds to be swept away whilst the synclinals were saved by being depressed below the action of the denudation agents; but it would not give results so decisive as that ultimate phase of a synclinal[1] (in combination with an anticlinal) developing a thrust plane, or reversed strike fault; whereby the Tal beds, and in some cases the nummulitics, would be actually thrust and buried under a capping of older beds; and so protected by them from all subsequent wear and tear of denudation. We are obliged to admit, from the evidence before us, that the synclinal, except in one instance, was found insufficient, and the sigma-flexure and reversed thrust plane sufficient, for their preservation; and in believing this we shall do no violence to thought, and the apparent remarkable coincidences become reasonable necessities.

A certain additional weight is given to these conclusions, when we remember that the position of the Siwalik and other upper-tertiary rocks with regard to the Outer formations, where they front the plains, is exactly what that of the Outer formations is

[1] Called a sigma-flexure, folded flexure, reflexed fold or overfold. See Heim's Atlas "Untersuchungen über den Mechanismus der Gebirgsbildung," and Lapworth's "Secret of the Highlands." *Geological Magazine*, 1883.

with regard to the schistose series. It has long since been shown by Mr. Medlicott and others that the later tertiary rocks (about the age of which there is no doubt) dip down against older Himalayan rocks, from which they are separated by a reversed fault; and there seems every reason to believe that the causes which produced this condition were simply a repetition in more recent times of a similar type of earth-movement to that which I have advocated above. In ages to come, when the Siwaliks have been worn away at their outer edge more completely by denudation, there will be left a narrow band of rocks analogous to the present reduced state of the Tal; and presenting the same phenomena of persistently dipping beneath much older beds.

It has now been proved: first, that the apparent order, among themselves, of the Outer formations near the Ganges, is their natural historical order; and, secondly, that the Inner schistose series is of older formation than the whole of the encircling Outer series.

It is satisfactory to note as a favourable issue that the complete proof now established shows that the chronological succession of the rocks as here interpreted, is a natural, and not a strained one: for, first, the more highly metamorphosed rocks are found to be the oldest; whilst decreasing age is similarly marked by a commensurate decreasing metamorphism. Secondly, the non-fossiliferous formations pose naturally as older than those which display fossils, whilst the latter, as we should expect, are together and the youngest; and, thirdly, the difficulty of the Kalogarhi gneissose mass is overcome; for since the schistose series, among which it appears, are the oldest beds, its presence whether it prove to be an archæan gneiss, which under pressure and high temperature, at extreme depths, has at some period been liquified, and so merited the name of granite; or whether it be an intrusion of subsequent date, *i.e.*, a granite in which contemporaneous or subsequent foliation has been superinduced by pressure—in either of these cases there is nothing so abnormal as to be improbable.

In this paper I have only touched on the main difficulty, ignoring for the present all less prominent questions, which a close scrutiny of the maps will suggest, *e.g.*, the unconformability of the members of the outer series amongst themselves and the marked unconformability indicated near the Sour and Kotedwar glens between the Tal beds and the schistose series. The map there shows the great thrust plane absent, and the Tal beds and nummulitics in an undisturbed synclinal. Hence the Tal beds are disposed indiscriminately on the schistose series, the purple slates, &c., and the massive limestone; a condition implying contortion and denudation such as to expose the schistose series at the time when the Tal beds were deposited. I have also refrained from going into more descriptive detail than was absolutely necessary to bring out the points of chief significance.

Above all, it seems to me that the foregoing results afford a useful lesson in enjoining the utmost caution and accuracy of mapping; in order that, amongst such intensely folded rocks, a right distinction may be drawn between ordinary dip planes and thrust planes; especially when the latter have a perfect parallelism in strike with the strike of the rocks, and hence cannot readily be recognized as differing in any way from ordinary dip planes. Extreme circumspection in this matter is a *sine quâ non* if good work is to be done in mountainous regions.

In conclusion, a few remarks may be made with regard to the connection between the district just described and other parts of Garhwal and Kumaun visited by me in the course of last season.

From the point where the east and west Nyar rivers meet, I went north-east up to the head of the east Nyar, finding nothing but the schistose series the whole way until Kainur was reached. There, the presence of more decided schists, and garnetiferous schists, heralded the incoming of more of the gneissose granite. Dudatoli, the culminating peak of the neighbourhood, like Kalogarhi in the district just described, is composed of that rock; and from it in a westerly direction extend bedded bands, strongly developed at first, but dying out gradually. All details are out of place here, as the work is still only half mapped; but I would wish to point out the exact correspondence between the gneissose granite, both in composition and in habit, here and at Kalogarhi. The only difference is, that it comes on more strongly, but at the same time more gradually: some of the first bed-like intrusions alternating with schists, as though the result of direct metamorphism. By tracing the beds laterally, however, it is seen that they die out away from the central mass of Dudatoli, and close in towards it; so that they are in reality but elongated "fingers" protruding from the Dudatoli massif.

Further north, beyond the head of the west Nyar river, we have a faulted junction, bringing in purple slates and the massive limestone along the Dobri-Danpur ridge; beyond which a thick set of diorites and quartzites make a first appearance. From here in a south-east direction towards Naini Tal we cross a similar set of formations.

One may then say (roughly generalizing) that the schistose series and gneissose granite about Ranikhet and Dwárahath are most probably representatives of like beds described in the foregoing paper; whilst the slates and massive limestone displayed about Naini Tal are, with equal probability, representatives of the purple slates and limestone also there described. It is to be noted, however, that the Tal beds, or at least the fossiliferous portion of them, are not seen near Naini Tal, and the nummulitics, though said to have been found by Messrs. Schlagintweit [1] are almost certainly absent also.

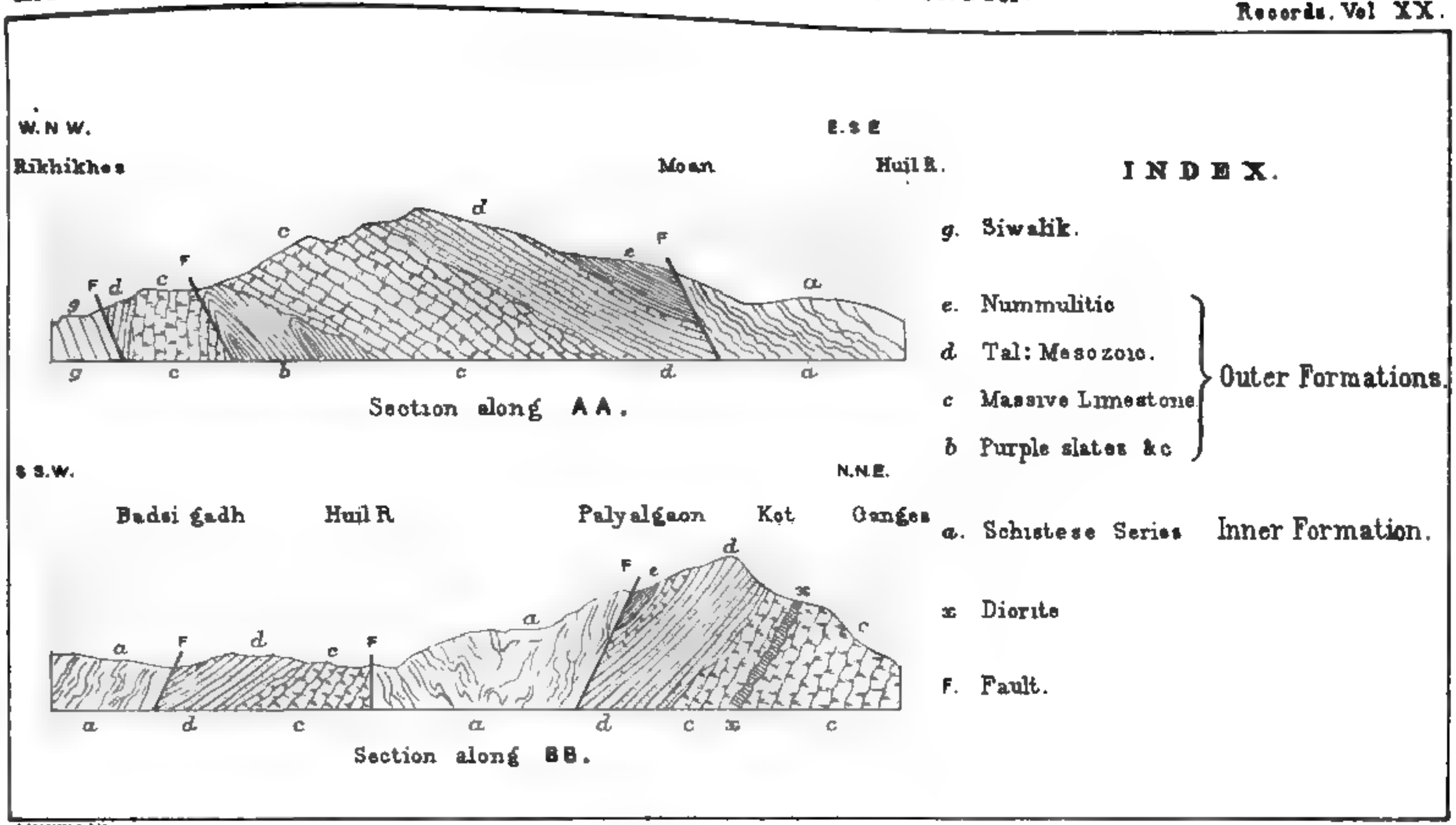
Notes on the Geology *of the* Garo Hills, *by* T. D. LATOUCHE, B.A., *Geological Survey of India.*

The main features of the geology of the Garo Hills have been known for several years and described in the Records and Memoirs of the Geological Survey,[2] but the valley of the Sumesary, where considerable fields of coal exist, is the only portion of the hills that has hitherto been examined in detail.[3] During the past

[1] See Manual of Geology of India, p. 609; also Journal, Asiatic Society of Bengal, Vol. XXV, p. 118.

[2] Records, Vol. I, Pt. 1, p. 11. Vol. VII, Pt. 2, p. 58. Mem. G. S. I., Vol. VII, p. 151.

[3] Records, Vol. XV, Pt. 3.



AMINULLAH

PART OF BRITISH GARHWAL. SECTIONS. *See the 1-inch Map.*

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- Sub-Himalayan (U. Tertiary).
- Nummulitic (L. Tertiary).
- Tál (Mesozoic).
- Massive Limestone.
- Purple slates, &c.
- Volcanic breccia.
- Schistose series Gárnitiferous.
- Diorite.
- Gneissose granite.
- Fault lines.

field season I commenced a systematic survey of the hills, starting from the already described sections on the Sumesary, and working westwards along the southern base of the main range of gneiss, which runs in a west-north-west direction through the centre of the district.

The formations represented in the Garo Hills are the following:—Gneiss, cretaceous sandstones with coal, nummulitic limestone with associated sandstones, and upper tertiary sandstones. A still more recent formation, consisting of terraces of gravel and boulders at a considerable elevation above the existing river courses, is extensively exposed in the south-western portion of the district, but I have not had many opportunities as yet of examining it.

In the adjoining Khasia Hills other formations intervene between the gneiss and the cretaceous rocks, *viz.*, the Shillong series, the Khasia trap and granite and the Sylhet bedded traps. Numerous dykes of a fine grained compact trap do occur intrusive in the gneiss of the Garo Hills, which may possibly represent some of the igneous rocks of the Khasia Hills, but in that case one would expect to find similar dykes intrusive in the Khasia Hill gneiss, and as far as I know they do not occur in it. The dykes in the Garo Hills are pretty generally distributed throughout the district, but are most numerous in the north-western portion of the hills, where it is rare to find a section of the gneiss without coming upon one or more of these dykes. They are generally narrow and coincident, or nearly so, with the strike of the gneiss, but sometimes appear to have been intruded horizontally along joint planes, and often show well defined columnar jointing perpendicular to the surfaces of contact. In many places where sections are not available these dykes betray their presence by the numerous rounded exfoliating blocks of greenstone, derived from the breaking up and weathering of the columns, which are scattered over the surface of the ground.

The cretaceous rocks, which rest immediately upon the gneiss, have hitherto received the greatest amount of attention in this district, because in some places they contain good seams of coal. The only workable seams, however, seem to be confined to the valley of the Sumesary and the country to the east of it, in which direction they extend to the Langrin coal-field in the south-west Khasia Hills. At the village of Aruak, only a few miles to the west of Siju on the Sumesary (where coal of good quality occurs), a considerable thickness of cretaceous rocks is exposed, resting nearly vertically against the gneiss, without a trace of coal. Still further to the west, on the head waters of the Nitai and Bogai rivers, the cretaceous rocks rest horizontally on a platform of gneiss, from 4 to 5 miles broad, which extends for about 14 miles along the base of the main range. Numerous sections are exposed in the river gorges, the total thickness of the sandstones being from 500 to 600 feet, but in no case did I find any trace of coal. At the southern edge of this platform of gneiss the cretaceous rocks bend over and quickly disappear beneath the nummulitic limestone and newer rocks. Further still to the west, below Tura, and on the Singmari plateau, the few exposures of coaly matter that do occur were long ago shown to be worthless. The question whether this coal improves towards the deep, which can only be ascertained by boring, still remains undecided; though from the fact mentioned above of its disappearance west of the Sumesary, it is not likely that such would be the case.

A white shaly indurated clay, or lithomarge, occurs in most places where the cretaceous rocks are exposed, in bands of 2 or 3 feet in thickness; when better communications through the hills are opened out, it may prove to be of some value as a pottery clay. There is a thick deposit of it in the station of Tura; where it has been used for white-wash. At present the Garos obtain the material they require for their rude pottery from beds of a stiff yellow clay which occurs locally immediately above the nummulitic limestone.

Conformably overlying the cretaceous sandstones is a series consisting of nummulitic limestone and fossiliferous sandstones with sandy shales. The main band of limestone always occurs at the base of the series, thin bands of limestone also occurring in places in the sandstones above. The thinning out of the limestone between the Sumesary and Damalgiri Thana, where in 1868 Mr. Medlicott noticed the western extremity of the bed in a thin band of rusty concretionary limestone, is very marked, as well as its rapid deterioration in quality. About 150 feet of it are exposed in the Bogai at Ganchi, but the whole is sandy earthy and nodular. The sandstones which overlie the limestone are fine grained, ferruginous, and generally show a tendency to become nodular. In these rocks fossils had previously been found only in one locality, *viz.*, on Nongkulang hill in the south-west corner of the Khasia Hills, where Colonel Godwin Austen collected a large number of specimens from sandstones immediately overlying the nummulitic limestone.[1] These were examined by Dr. Stoliczka, who remarked that none of the species appeared to be identical with those known from the nummulitic rocks of the district. Unfortunately there are very few of Colonel Godwin Austen's specimens in the museum, nor do any of them appear to be those examined by Stoliczka, while no description of the fossils from the nummulitic limestone of these hills has been published; so that I have been obliged to compare my specimens with those described in D'Archiac and Haime's nummulitic fauna of Sind, and with European species. Among them I have been able to identify the following with more or less certainty:—

From the cart road between Tura and Mankarchar, about 7½ miles from Tura—

Cardium greenoughi.	Corbulomya triangula.
Cytherea orbicularis.	Venus nucleus.

From scarp west of Warimagiri village (marked Warogiri on map)—

Arca subfiligrana.	Fusus, ? javanus.
,, sabuletorum.	Fusus aciculatus.
Cardium tenuisulcatum.	Conus sp.
,, austeni.	Ampullaria pygmæa.
,, anomale.	? Mitra sp.
,, sp.	Solarium sp.
Cyrena distincta.	? Achatina fragilis.
Nucula sp.	Cassis sp.
Ficula pannus.	Turbinolia.

From the Kilburn stream near Khenigiri village—

Mactra sp.	Crassatella propinqua.
Lima bulloides.	Rostellaria lucida.
Turritella granulosa.	

[1] Jour. As. Soc. Bengal, Vol. XXXVIII, Pt. 2.

From about 1 mile east of Khenigiri village—

Cardium multisquamatum.	Cytherea sp.
Cardita subcomplanata.	Crassatella sulcata.
Isocardia sp.	Pecten decussatus.
Cypricardia sp.	Rostellaria lucida.
Arca capillacea.	Natica sp.
Venus sp.	? Balanophyllia

From scarp east of Bogai river near Ganchi—

Rostrum of Balanus.

From ridge between Damakchi and Rongpha streams near Duching village—

Crassatella bronnii.	Cyrena sp.
Cytherea orbicularis.	Pecten sp.
" obsoleta.	Rostrum of Balanus.
Lucina sp.	

The above species are nearly all found in the eocene deposits of Europe. All the fossils occur as casts in fine sandstone, the original shell being in no case preserved, so that it is often difficult to make out the specific characters. The specimens found at Nongkulang hill by Colonel Godwin Austen belong to the genera *Conus, Dolium, Dentalium, Cardita, Cardium, Tellina, Nucula, Leda, Cucullæa,* &c.,[1] but the names of none of the species are given. There is little doubt however that these fossiliferous sandstones should be classed as nummulitic owing to the thin bands of limestone containing minute nummulites, which are intercalated with them. One of these beds (in the Mandar stream, about 3 miles west of Emangiri) which is well up from the bottom limestone band, contains numerous specimens of *Operculina canalifera*, a species very common in the nummulitic limestone of Cherra.

The fossiliferous sandstones pass up into a mass of very similar sandstones, which attain a thickness of about 1,200 feet in Joksongram hill near Shushung Durgapur. In these no fossils have as yet been found, partly, I believe, owing to the coarseness of the sandstones, some of them being almost conglomerates and not suited to the preservation of casts. I am hopeful, however, that further search will reveal the presence of fossils in these rocks, without which their separation from the underlying nummulitics will be a matter of great difficulty.

Note on some Indian image-stones, *by* COLONEL C. A. MCMAHON, F.G.S.

Gaya (Gya): Nos. 7—200. 7—201. 7—202. 7—203. 7—205.

The specimens were sent to me by Mr. Medlicott, Director of the Geological Survey, and I have given the Survey register numbers for facility of reference.

Gaya is a very sacred place both for Hindus and Buddhists, and this stone is extensively worked into images and utensils of various kinds for traffic with the pil-

[1] Mem. G. S. I., Vol. VII, Pt. 3, p. 9 note.

grims. A reference to its mode of occurrence in the field will be found in Vol. II of the Records of the Geological Survey, page 42.

M.—These samples are all so similar one to another under the microscope, that a general description of them is all that is requisite. The matrix of the rock appears to be quartz, though free quartz is not prominent in all the slices. It is abundant in No. 201, but is almost absent in No. 205. The quartz is very pure and limpid, and contains no liquid cavities.

The most prominent feature in the rock, perhaps, is the abundance of chlorite and sericite which it contains; the two minerals being intimately mixed up with each other. Under the microscope sericite in several respects much resembles talc; but some of the colourless, foliated, mineral seen in the field of the microscope is certainly a mica, and from the amount of water small pieces of the rock yield in a glass tube under the blow pipe, I think it is safe to assume that the whole of it is sericite. Indeed, the flame of a spirit lamp, without a blow-pipe, supplies sufficient heat to make the rock give up water abundantly. No. 205 is highly micaceous in its macroscopic aspect.

Felspar, all of which belongs to the triclinic system, is also a prominent feature in the rock taken as a whole. It is entirely wanting in my slice of No. 205 (in which free quartz is also extremely sparse), and it is very subordinate to the quartz in No. 201; but it is present rather abundantly in the other slices. In No. 203 it occurs in sufficiently large, and sufficiently numerous crystals, to impart a speckled appearance to the hand-specimen. It is beautifully twinned in single crystals, or in groups of crystals; but in no case does it exhibit any external crystallographic outline, being, for the most part, in more or less rounded nodules. Magnetite or ilmenite, apparently the latter, is present in all the slices, except, No. 205, where it has been converted into a substance resembling leucoxene. The iron contains numerous inclusions, or intergrowths, of chlorite.

Some of the slices contain a few micro-garnets; No. 201 contains a very little schorl, and No. 203 a minute sphene.

The rock appears to be of metamorphic origin. Nos. 201 and 203 have, macroscopically considered, a specially trappoidal appearance; but the rock presents nothing under the microscope to suggest an igneous origin. The quartz is not like the quartz of granite, or its allies; and the rounded character of the felspar crystals appears to me to be due to segregation having taken place in an imperfectly plastic mass, and not to have had its origin in the solvent action of an igneous matrix. The felspar contains no inclusions of the matrix.

Dhalbhum : E. 30.—A light grey coloured rock, slightly soapy to the feel, and of more "cheesy" type, than the previously described specimens. Under the microscope it is seen to be composed of chlorite, a micaceous-talcose mineral that may be either a hydro-mica (sericite) or talc, magnetite, sphene, and calcite; the latter is not inconsiderable in amount. This is a more orthodox potstone. In his Geology of Manbhum and Singhbhum[1] (of which latter district Dhalbhum is a sub-division) Mr. Ball mentions eight localities where this rock has been extensively worked. It occurs in thick beds in the 'sub-metamorphic series.'

Gaur : Nos. 7—244 and 7—246.—Principally used for carved work in the ruined

[1] Memoirs Geol. Sur. Ind., Vol. XVIII, p. 148.

buildings of Gaur, in the Maldah District, the ancient capital of Bengal; but the actual specimens are from the famous Adina mosque, at Panduah, 20 miles north-east of Gaur. It is not known where the stone used for these buildings was quarried. The ruins are in the delta of the Ganges, and the nearest (25 miles) rocks are the Rajmahal traps, beyond the Ganges. In appearance Nos: 244, 246 look like argillites, but they do not greatly differ in macroscopic aspect from some of the Gya pot-stones. They might pass for very fine grained varieties of No. 7—202.

Nos. 7—244 and 7—246 consist of very minute grains of quartz averaging about one thousandth part of an inch in diameter (the largest is under three thousandths of an inch in diameter), and minute fibres of mica (probably a hydro-mica) set in a structureless base that represents, I apprehend, the original setting of fine mud. In this ground mass, there are starred about skeleton prisms—ghost-like forms, without bones or substance—of what may possibly be the spirits of hornblende in the hades of metamorphism. They have no action on polarised light; their ends are unfinished; and in neither of my slices are cross-sections of the prisms to be obtained. Indeed, they have so little substance about them that they have not displaced, or assimilated, the quartz grains of the matrix which show sharp and clear within them, and have been wholly undisturbed by the formation of the prisms. Evidently their genesis has been due to segregative action. These crystals are of dark greenish colour in transmitted light; but they are without internal structure and exhibit no dichroism. It is impossible to give them any definite mineralogical name.

On applying high powers these slices are seen to contain very numerous micro-sphenes from one to one-and-a-half thousandths of an inch in length. The quartz grains are sub-angular—none are distinctly rounded. The fibres of mica all point in the same general direction, but the rock does not present any distinct lamination.

This argillite may possibly come from some sedimentary beds intercalated with the Rajmahal traps (I am personally ignorant of the locality), but there is nothing in the structure of the argillite to indicate any connection with it and the trap. In composition, too, it is seen under the microscope to be different from the Gaya pot-stones. The latter are essentially micaceous-chloritic-schistose rocks, or talcose-micaceous-chloritic rocks. The Gaur stones are fine grained sandy argillites. Both are metamorphic sedimentary rocks. The Gaur rock is an interesting one to the student of metamorphism.[1]

In the Gaya potstones I have felt considerable difficulty in discriminating between hydro-micas and talc. Some of these rocks undoubtedly contain mica; a silvery mica, for instance, is very prominent in No. 7—205, even when viewed macroscopically; but it is, I think, in the present state of our knowledge, impossible to say from optical evidence whether the micaceous-talcose mineral present in these rocks is a hydro-mica (presumably sericite) or talc. M. M. Fouqué and Michel Lévy in their *Minéralogie Micrographique* give some useful hints for discriminating between sericite and talc, but I have not found them sufficient to enable me to satisfy my mind in this case, though I have bestowed considerable labour on the subject.

[1] Colonel McMahon's decision that this Gaur stone is not trappean, increases the difficulty as to whence it can have been derived. The known intertrappean beds of the Rajmahal hills are utterly different from this stone, and always exhibit distinctly their sedimentary origin; so, if not igneous, the Gaur stone can hardly have come from that ground, and all other rocks *in situ* are very distant.—H. B. M.

On Soundings *recently taken off* Barren Island *and* Narcondam, *by* COMMANDER A. CARPENTER, R.N., *H. M. I. M. S. 'Investigator,' the Officer in charge of the Marine Survey of India.*

In February 1884, the volcanoes of Barren Island and Narcondam, in the Bay of Bengal, were surveyed topographically and geologically by Captain J. R. Hobday and the undersigned, the results of our work being published in the Memoirs of the Geological Survey of India (Vol. XXI). In the report alluded to I pointed out[1] that scarcely any reliable soundings had been taken off the shores, and that, although there was reason to believe that the volcanoes rose from very deep water, almost nothing was known on this point with certainty. The projected scientific cruise of H. M. I. M. S. *Investigator* seeming to afford a possible opportunity for examining the ground, I drew up a short note respecting the desideratum in question, which was forwarded by the Director of the Geological Survey to Captain A. Carpenter, the Officer in charge of the Marine Survey of India, in command of the *Investigator*. Our acknowledgments are due to him for the readiness with which he fell in with the suggestion offered, and for the charts, of which reduced copies are appended herewith, giving the results of soundings taken by him last May.

The following sections have been plotted from the above soundings, combined with the sub-aerial contours as given by Captain Hobday.

In respect to Barren Island, especially, they show very clearly how insignificant the visible portion of the volcano is, in comparison with the huge mass of ejecta which has been piled up beneath the waves. The volcano certainly rises from a depth of not less than some 800 fathoms, giving a total height from the sea-bottom of not less than 6,000 feet, as the volcano stands at present, or some 8,000 before the upper part of the outer cone was blown away.[2] But the outward slope is still continued at the deepest soundings taken, indicating that the base of the sub-marine mountain (or the sea-floor) must be sought still further out, and that the entire altitude is still greater than that given.[3]

Most sections of the inner cone present an angle of 32°, while the average slope of the outer cone above water has been estimated at about 25°.[4] Of the sub-marine slopes plotted B has, near the shore (*i.e.* inside the first sounding), the remarkably steep inclination of $32\frac{1}{2}°$, the sub-aerial slope above being only 21°. At C the corresponding inclinations are nearly equal, or 28° and $30\frac{1}{2}°$. A shelves more gradually, or at 19°, which may perhaps be attributed to the latest outpour of lava through the breach into the sea.[5] D is not steeper near the shore than considerably further out.

Taking the entire lines of sounding into consideration the mean inclinations for equal distances are fairly uniform with one exception. Thus the inclinations of A,

[1] Memoirs, Geol. Surv. of India, Vol. XXI, pp. 258, 281.

[2] *Ibid*, p. 257.

[3] Since the above was written, later soundings, given in the letter published below, have been received from Captain Carpenter, which indicate a probable total height of some 8,000 ft., at present, and 10,000 formerly.

[4] *Op. cit.* 257.

[5] *Vide* Map, *Op. cit.*

B, and C for the first $2\frac{1}{4}$ miles from shore (the total length of the shortest line B) are respectively $16\frac{1}{2}°$, $18\frac{1}{2}°$ and $20\frac{1}{2}°$.

The reason why the water is comparatively shallow to S.S.W. of the volcano (along the line D) is not very apparent. Any effect caused by the action of the wind, during the eruption of fragmentary ejecta, would be sought for on the opposite side of the island, *i.e.* to leeward of the south-west monsoon.[1] According to the charts of the Bay of Bengal, just issued by the Meteorological Department, the currents are very irregular in that part of Bay, so that the effect in question can scarcely be attributed to a persistent set of detrital material in one direction. The shallow water is in the continuation of the line joining Narcondam and Barren Island, a fact which lends some little support to the idea that one or more sub-marine eruptions have occurred there; but in this case one would expect a more irregular sea-bottom than the soundings indicate. It may be, indeed, that eruptions of ash, &c., have occurred as suggested, and that the material has been distributed over the surface by the action of currents.

Both sections of Barren Island show along the sub-marine slopes that curvature of outline, due to gradually decreasing inclination, which is so common in sub-aerial volcanoes, and of which an admirable example is to be found in the great Japanese volcano of Fusiyama.

Samples of the material brought up by the lead from nine of the soundings[2] (including the deepest and furthest out) were sent to the Museum by Captain Carpenter. The stony matter consisted in every case of grains and small pellets of black volcanic ash. With reference to organisms Captain Carpenter writes—"I consider that there was a remarkable paucity of marine foraminifera deposit *over* the volcanic or pluvial detritus in the depths round Narcondam Island, and a complete absence round Barren Island for many miles, which appears to show the slowness with which marine deposits are made in that portion of the ocean. You will notice on the tracings of our soundings that I have noted the occurrence of globigerina and pteropod shells round Narcondam, but only in three cases was the major part of the formation composed of marine ooze." That there should be more organic deposit on the sea-bottom off the shores of an extinct volcano, like

[1] *Op. cit.*, p. 255.

[2] The soundings in question were:—

Point to which bearing was taken.	Magnetic bearing.	Depth in fathoms.	Surface Temp. of Sea.	Temp. at bottom of Sea.
Cone	S. 76° 30′ E.	855		
Ditto	S. 78° 45′ E.	644	85°·8 F.	43°·0 F.
Ditto	S. 76° 50′ E.	456		
Peak, 1,025 ft. . . .	N. 64° 45′ W.	433		
Ditto	N. 67° 45′ W.	641		
Cone	S. 12° 55′ W.	782	...	41°·8 F.
Peak, 1,032 ft. . . .	N. 33° 10′ E.	299		
Ditto	N. 31° 28′ E.	413		
Cone	S. 21° 51′ E.	325		

The surface temperatures at two other soundings were 86°·0 and 86°·5. The temperatures given above are corrected for pressure.

Narcondam, than round an active one like Barren Island, is what might perhaps be expected. Such deposits in the latter case are always liable to be buried beneath showers of ash.[1]

It will be noticed that the soundings off Narcondam are on the whole shallower than those round Barren Island. To a certain, but probably to only a small, extent this may be due to the raising of the sea-bottom through the wash of detritus off the flanks of the extinct volcano.

It would seem, however, that the minimum depth assignable to the sea-floor cannot be less than some 600 fathoms, which would give a total height to the volcano of about 6,000 feet.

F. R. MALLET.

Since the above was written, the subjoined interesting letter, from Captain Carpenter, dated 22nd November, has been received.

"In continuation of my letter No. 903 of 1st November 1886, I have to acquaint you that on passage to Burma this month I took deeper soundings between Barren Island and Narcondam Island, obtaining these casts:—

Fathoms.	Miles.		
1,140	25½	N.	of Barren Island
1,010	24½	S.S.W.	of Narcondam.
362	9½	N.N.E.	of do.
290	16	N.N.E.	of do.
70	52	N.N.E.	of do.

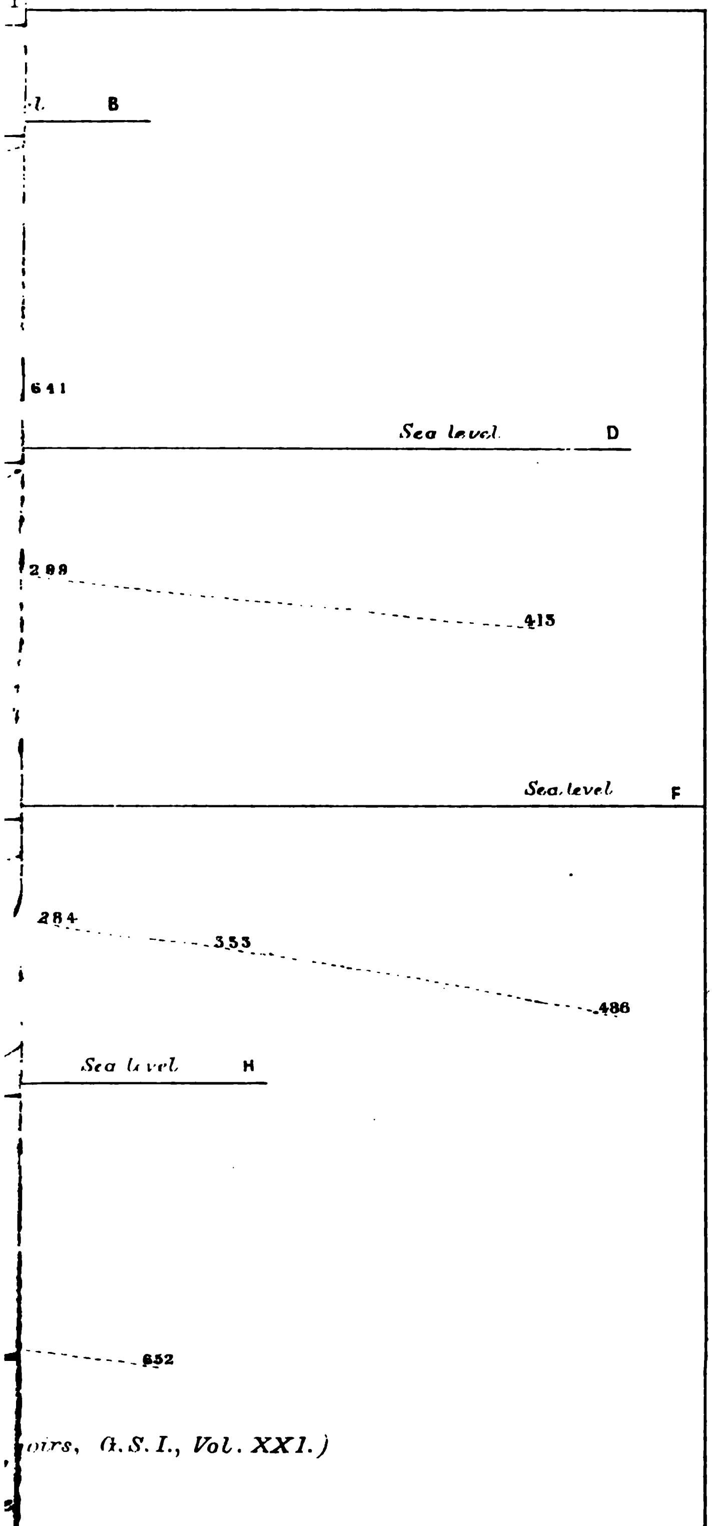
On the tracing sent you last July there is a cast of 411 fathoms at 4½ miles N.N.E. of Narcondam; and on the published charts there is about 50 fathoms at 70 miles N.N.E. of it, from which the depths shoal gradually to the delta of the Irrawaddy. It therefore appears that the deltaic shelf extends right out to Narcondam.

A thermometer sent to the bottom at the 1,010 fathoms cast shewed 41°·2 corrected temperature Fahrenheit. The usual temperature of the Bay of Bengal at 1,010 fathoms is 37°·6, and the temperature 41°·2 is that suitable to a depth of 740 fathoms. If we look at a chart of the east side of the Bay of Bengal we see that there are three inlets into this partly enclosed sea. One is only 150 fathoms deep, *viz.*, Preparis Channel; one is not marked with any depth, *viz.*, the Ten degrees channel; and one has 760 fathoms marked nearly on the ridge between Acheen Head and Great Nicobar.

As you are doubtless aware, the cold of the great ocean depths is due to the gradual flow of Arctic and Antarctic waters towards the equator, and it has been shown by the *Challenger* expedition that where the cold flow rises to pass over a ridge it becomes warmed, and does not again lose its heat on descent into a deeper bed.

This temperature then at 1,010 fathoms, equal to the normal temperature at 740 fathoms, seems to prove, as far as one observation can be a proof, that no greater depth than 740 fathoms exists on the ridges between Acheen Head and Great Nicobar, nor in the Ten degrees channel."

[1] While on the subject of Barren Island, I should mention that Mr. Daley, Apothecary of the *Investigator*, landed on the 28th April, and noted the temperature of the hot spring as 110° F. This is interesting as showing that the decrease of temperature which has been going on during the last quarter of a century (Mem. Geol. Surv. of India, XXI, 275) still continues. Captain Carpenter remarked that "from the ship the thin column of steam (from the central cone) could be barely seen at 3 miles distance."


B
641
Sea level
D
289
415
Sea level
F
284
353
486
Sea level
H
652
oirs, G.S.I., Vol. XXI.)

AMINULLAH.

Note on a character of the Talchir boulder beds, *by* W. T. BLANFORD, F.R.S.

There is a character of the Talchir boulder bed to which I do not think attention has been called, but which appears to me to throw some light on the origin of the deposit. This is the combination of large size with thorough rounding of the boulders.

In many places boulders exceeding a foot in diameter are as common as smaller fragments, sometimes, if my memory is correct, more abundant, whilst thoroughly rounded masses of 2 and 3 feet in diameter are of frequent occurrence, and even larger rounded boulders may be found. I have measured more than one 6 feet in extreme length. The boulders are often almost, or quite, spheroidal in shape, evidently from the effect of being rolled.

Now rolled boulders of this size, exceeding a foot in diameter, are, I believe, of extremely rare occurrence on sea coasts. I have not for many years had an opportunity of visiting a stormy coast composed of hard rocks, but so far as I can learn from enquiry large rounded boulders are not often met with in any quantity. In large rivers such rounded masses are also infrequent, and are only found in very rapid streams, such as the Nerbudda. When they do occur, they are few in number, compared with the smaller pebbles. Large rounded blocks with but few associated smaller fragments are, so far as my experience serves, characteristic of hill or mountain torrents.

I may be mistaken on these points, but I think the question is worth raising. If I am correct it seems probable that the Talchir boulders are derived from rapid streams. The beds themselves however in their fine texture and general absence of false bedding indicate deposition from still or slowly moving water. My impression is that they were formed in large marshes or lake-like expansions of great river valleys. The utter unconformity between the Talchirs and all underlying formations indicates a great change in the condition of the country at the commencement of the Gondwána period, a change by which an area of subaerial denudation was converted into one of partial deposition. If the change, as is probable, was one diminishing the fall in the river valleys, a natural result would be that in portions of those valleys there would still be a sensible though diminished fall, whilst other parts would be converted into large marshes or shallow lakes. In the latter the Talchirs may have been deposited, the boulders being floated in from stream beds in the surrounding hills. The only known agent in floating such boulders is winter ice, especially when broken up by floods in spring; water weeds and roots of trees could not account for the number and frequent occurrence of the boulders in so many different places. The circumstance that the boulders are of irregular occurrence, abundant in places, in others absent, is quite in accordance with the theory put forward.

It should be understood that the Talchir beds to which I refer in this note are those of Bengal and the Central Provinces generally. Mr. R. D. Oldham has recently shown that the boulder beds noticed by myself some years ago in Western Rajputana are also probably Talchirs, but I quite agree with him that these differ from the typical deposits in several respects.

Analysis of Phosphatic Nodules *from the* Salt-range, *Punjab*, *by* H. WARTH, PH.D.

The analysis shows the following composition :—

Insoluble silica, &c.	4
Phosphorus pentoxide	30
Carbon dioxide	4
Sulphur trioxide	2
Chlorine	trace.
Aluminium	"
Ferrous oxide	2
Magnesium oxide	2
Balance—Calcium oxide, water, organic matter and loss	56
	100

The proportion of phosphorus-pentoxide is equivalent to 66 per cent. of ordinary pure calcium phosphate.

These nodules occur in the shales above the coal in the eocene strata of the Eastern Salt Range in the Punjab.

They are covered all over with peculiar circular pores. Very often shells are also found metamorphosed into the same phosphatic mineral.

The nodules are very numerous about Dandot Colliery and the neighbourhood. The quantity of material (as far as it was followed up) was not found sufficient for practical utilisation, but the occurrence is so far of interest as it affords another proof of the presence of phosphatic mineral in the sedimentary strata of India.

ADDITIONS TO THE MUSEUM.

FROM 1ST OCTOBER TO 31ST DECEMBER 1886.

A series of 16 specimens in mahogany case, illustrating the extraction of copper from cupreous pyrites.

PRESENTED BY THE THARSIS SULPHER & COPPER CO., LD., GLASGOW.

Nine specimens of minerals from different localities in England.

PRESENTED BY THE BRITISH MUSEUM.

Specimens of magnetite and limonite and steatite from Gangai, Jabalpur district.

PRESENTED BY MR. C. W. MCMINN, C.S.

ADDITIONS TO THE LIBRARY.

FROM 1ST OCTOBER TO 31ST DECEMBER 1886.

Titles of Books. *Donors.*

ALLEN, *Alfred H.*—Commercial Organic Analysis, 2nd edition, Vol. I. 8° London, 1885.

BALL, *Valentine.*—Observations on lion-breeding in the gardens of the Royal Zoological Society of Ireland. 4° Pam. Dublin, 1886. THE AUTHOR.

BECKER, *George F.*—The Washoe Rocks. 8° Pam. San Francisco, 1885. THE AUTHOR.

DABNEY, *Charles W.*—Methods of analysis of Commercial Fertilizers. 8° Pam. Washington, 1885. REVENUE & AGRICULTURAL DEPARTMENT.

DESLONGCHAMPS, *Eugène Eudes.*—Notes Paléontologiques. Vol. I. 8° Paris, 1863-1869. J. WOOD-MASON.

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January, 15th 1887.

Government of India Central Printing Office.—No. 37 D. G. Survey—4-2-87.—720.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1887. **[May.**

ADDENDUM ET ERRATUM.

Page 66.—The eocene chelonian *Hemichelys* is entirely devoid of epidermal plates, and may be referred to the same family (*Carettochelydidæ*) as the existing *Carettochelys* of New Guinea. The larger chelonian from the same deposits belongs to the South American genus *Podocnemis*.

" 71.—*Ceratodus* has been found in a fossil state from the permian to the cretaceous.

R. L.

ductory portion of the original paper, in which the names of the chief workers in this field of enquiry are recorded, as there is no essential alteration to be made regarding them. Some introductory observations on the general relations of the Indian fossil vertebrates have likewise been omitted, as well as all the references: the nomenclature employed has been amended in many instances.

The plan of the original paper has been in the main adhered to; but the order in which the classes of the Vertebrata are taken has been reversed, and their history is traced from the newest to the oldest horizons, instead of from the oldest to the present time. At the end a systematic synopsis of all the known forms is given, arranged according to their geological distribution. The great majority of the species will be found described or noticed either in the 'Palæontologia Indica,' or in the writer's 'Catalogue of the Fossil Mammalia in the British Museum.' Synonyms have been in most cases omitted.

It is hoped that this brief summary will enable the reader to grasp the chief features of the past vetebrate life of India without the trouble of wading through the somewhat bulky literature in which its history is more fully recorded.

Titles of Books.	*Donors.*
WASHINGTON.—Bulletin of the Philosophical Society of Washington. Vol. VII. 8° Washington, 1885.	SMITHSONIAN INSTITUTE.
„ Bulletin of the United States Geological Survey. Nos. 24-26. 8° Washington, 1885.	UNITED STATES GEOLOGICAL SURVEY.
„ Monographs of the United States Geological Survey. Vol. IX. 4° Washington, 1885.	UNITED STATES GEOLOGICAL SURVEY.
„ Contributions to North American Ethnology. Vol. V. 4° Washington, 1882.	REVENUE AND AGRICULTURAL DEPARTMENT.
„ Descriptive catalogue of the Government Publications of the United States. September 5th, 1774 to March 4th, 1881. By Ben. Perley Poore. 4° Washington, 1885.	REVENUE AND AGRICULTURAL [illegible]
YOKOHAMA.—Mittheilungen [illegible]	

Government of India Central Printing Office.—No. 37 D. G. Survey—4-2-87.—720.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1887. [May.

The Fossil Vertebrata *of* India, *by* R. LYDEKKER, B.A., F.G.S., &c.

INTRODUCTORY.

In the 'Journal of the Asiatic Society of Bengal' for the year 1880 there appeared a paper by the writer under the title of a 'Sketch of the History of the Fossil Vertebrata of India,' in which every species of fossil vertebrate then recorded from India was mentioned; while there was also given a short summary of the labours of those palæontologists who had written on the same subject. The same paper was republished in a more expanded form in the 'Records' for 1883, bringing up the information to that date. Since the publication of the latter paper owing to the completion of the description of the Siwalik and Gondwana vertebrates a great increase in our knowledge of the subject has been obtained, and it has accordingly been thought advisable to republish its substance, with such additions and alterations as are necessary to bring it up to the present time. In many instances these alterations have been so extensive as to have made it necessary to rewrite a great portion of the paper. As in the previous issue, it has been thought better to omit the introductory portion of the original paper, in which the names of the chief workers in this field of enquiry are recorded, as there is no essential alteration to be made regarding them. Some introductory observations on the general relations of the Indian fossil vertebrates have likewise been omitted, as well as all the references: the nomenclature employed has been amended in many instances.

The plan of the original paper has been in the main adhered to; but the order in which the classes of the Vertebrata are taken has been reversed, and their history is traced from the newest to the oldest horizons, instead of from the oldest to the present time. At the end a systematic synopsis of all the known forms is given, arranged according to their geological distribution. The great majority of the species will be found described or noticed either in the 'Palæontologia Indica,' or in the writer's 'Catalogue of the Fossil Mammalia in the British Museum.' Synonyms have been in most cases omitted.

It is hoped that this brief summary will enable the reader to grasp the chief features of the past vetebrate life of India without the trouble of wading through the somewhat bulky literature in which its history is more fully recorded.

CLASS I.—MAMMALIA.

Pleistocene and later deposits.—The mammals of the pleistocene and later deposits are generally but imperfectly known, although the Karnul caves have yielded very important information in regard to those of Southern India. As the pleistocene ossiferous strata are distributed in patches, very frequently in the valleys of the great rivers, the remains from the more important of these areas must be treated of separately. The most important localities are the caves of Karnul; other parts of Madras and the Deccan; and the valleys of the Jamna, Narbada, Pemganga, Kistna, and Godavari, with their numerous tributaries. It is moreover not improbable that the topmost strata of the Sub-Himalayan Siwaliks should also be referred to the pleistocene. In many instances, as in the delta of the Ganges, it is difficult, if not impossible, to draw any satisfactory line of distinction between the pleistocene and the prehistoric deposits, and the two are accordingly considered together. The presence in any stratum of the remains of *Hippopotamus*, or other genus not now found living in India, is considered as fair evidence for assigning such deposit to the pleistocene.

Human remains and neolithic implements have been obtained in the alluvium of the plains in many localities, and frequently at considerable distances below the surface; the former are generally very imperfectly preserved and have never been carefully examined. Polished celts are abundant in many places, particularly in Burma and the Banda district of the North-West Provinces. The prevailing types are elongated forms with oval section, wedges, and the 'shouldered' form. Among the mammals, specimens of the teeth and jaws of a *Macacus* from the alluvium of Goalpara, in Assam, may belong to *M. sinicus*, while others from Madras have been provisionally referred to *M. rhesus*. Molars of the Indian elephant occur in the alluvium of the plains. A last upper molar of *Rhinoceros unicornis*, in the Indian Museum, was obtained from a turbary in Madras, and indicates the former extensive range of this species; and it may be observed in passing that the range of other species of the genus was probably more extensive than at present, even in the historic period, since it has been inferred that the species hunted by Akbar on the banks of the Indus was *R. sondaicus;* this inference being founded on the improbability of its being possible to kill *R. unicornis* by means of arrows, with which Akbar's animals were destroyed. *Sus cristatus* has also been obtained from the turbaries of Madras and Calcutta. Antlers, horn-cores, and teeth of undetermined species of *Bos* or *Bubalus* and *Cervus* have been obtained from the alluvium of various districts in the plains, and from raised beaches in Kattiawar. The mammalian fauna of the caves in the Karnul district of Madras besides including a large number of species still found living in India, which are mentioned in the list given in the sequel, also comprises a species of *Cynocephalus; Hyæna crocuta* of South Africa; a small *Viverra* termed *V. karnuliensis*, which presents characters connecting it with the Siwalik *V. bakeri;* the African *Equus asinus;* a larger undetermined species of the same genus; an atelodine rhinoceros named *R. karnuliensis*, apparently allied both to *R. etruscus* and *R. bicornis;* a large undetermined antelope; a peculiar species of large *Sus* named *S. karnuliensis*, which is apparently intermediate between *S. cristatus* and the Siwalik *S. falconeri;* a *Hystrix* named *H. crassidens;*

a species of *Atherura* (*A. karnuliensis*); and the large *Manis gigantea*, which is now confined to Western Africa. The peculiar Indian genera *Boselaphus* and *Tetraceros* are represented by the existing species; and the fauna as a whole is remarkable for the mingling of African and modern Indian forms, and also for its connecting the existing fauna of the country with that of the Siwaliks, which likewise presents a remarkably Ethiopian facies, as is exemplified by the presence of *Troglodytes*, *Cynocephalus*, *Hippotragus*, *Cobus*, *Alcelaphus*, *Giraffa*, *Hippopotamus*, *Struthio*, &c. Human remains occur in the caves among those of the extinct mammals.

From the laterite of Madras palæolithic implements and a human platycnemic tibia have been obtained.

From the alluvium of the Kistna valley, in the Deccan, a part of the skull and mandible of a rhinoceros has been described under the name of *Rhinoceros deccanensis*. This species belongs to that section of the atelodine group having molars of the Sumatran type, and is characterised by the strong cingulum on the upper premolars. Remains of a bovine, which is not improbably *Bos namadicus*, have also been obtained from the same deposits, and, with the last-mentioned specimens, are in the Indian Museum.

From the ossiferous gravels of the Narbada palæolithic implements of a rude form have been found associated with bones of extinct Mammalia. The Carnivora are represented by a small species of bear (*Ursus namadicus*), of which there are a maxilla and a tibia in the British, and a canine in the Indian Museum; while a large species of *Felis* is indicated by the distal extremity of a femur in the former collection. Of the Proboscidea, there is *Elephas namadicus*, characterised by its prominent frontal ridge, whose molars very closely resemble those of the European *E. antiquus*. There is one fine cranium in the British Museum, and there are three other crania in the Indian Museum. The stegodont group of the genus is represented by *E. ganesa*, of which there is a fine tusk in the Indian Museum; and very probably by *E. insignis*. The Perissodactyla are represented by *Rhinoceros unicornis* of which the Indian Museum has two molars; and by a little-known and apparently extinct form to which the name *R. namadicus* has been applied; there is a scapula of this species in the last-named collection. There is also a species of horse (*Equus namadicus*) which seems to be a survivor from the Siwaliks, and is allied to the existing species of the genus. Among the Artiodactyla three species of bovine animals have been described, *viz*., *Bos namadicus*, a species showing some affinity to the Asiatic group *Bibos*, of which there is a magnificent skull in the Indian Museum; a *Bubalus* now identified with the existing *B. buffelus*, but formerly regarded as distinct and named *B. palæindicus*; and *Leptobos fraseri*, which is sometimes hornless, and is represented by some fine skulls in the British Museum. A species of nilghai, of which there are two broken crania in the same collection, has been named *Boselaphus namadicus*; it is distinguished from the living species, among other characters, by the horns being placed nearer to the orbits. The deer are represented by *Cervus aristotelis*, *C. porcinus*, and perhaps *C. duvaucelli*. The existing *Sus cristatus* makes its first appearance in these beds, which also contain two species of *Hippopotamus*, in one of which (*H. namadicus*) there are three pairs of small incisors, while in the other (*H. palæindicus*) there are two pairs of large incisors, but the second pair are reduced to very small dimensions, and may have been absent in the

adult. Some incisors in the Indian Museum indicate the presence of an undetermined genus of murine rodent.

From the pleistocene of the Jamna valley only four mammals have been specifically determined with any certainty, *viz.*, *Elephas namadicus*, *Bubalus buffelus*, *Hippopotamus palæindicus*, and the living *Antilope cervicapra;* the latter being known by a horn-core in the Indian Museum. In addition to these, remains of a species of *Semnopithecus*, *Sus*, *Boselaphus*, *Equus*, *Mus* (?), and of a *Rhinoceros* furnished with lower canines, have also been obtained. A *Felis* as large as the existing tiger is indicated by a scapholunar bone in the Indian Museum: this species was very probably the same as the Narbada form, and may have been either *Felis tigris* or *F. leo.*

The pleistocene of the Pemganga valley has yielded remains of *Bos namadicus*, a *Boselaphus*, and *Hippopotamus palæindicus.*

The remains from the Godavari deposits have not yet been satisfactorily determined.

Pliocene—The horizontal lacustrine strata of Hundes in Tibet, which are provisionally regarded as of pliocene age,[1] have yielded a small number of mammalian remains, among which is a tooth referred to a species of *Hyæna*. Bones belonging to some form of horse have also been obtained, among which a cannon-bone in the collection of the Geological Society indicates a species of *Hipparion*. Several limb-bones and a fragment of an upper molar of a rhinoceros are also known, but they are too imperfect for specific determination. The other known fossils belong to ruminants; the best preserved specimen being the greater portion of the cranium of an antelope, provisionally referred to the living Tibetan genus *Pantholops*, under the name of *P. hundesiensis;* this specimen cannot now be found, but is figured in Royle's "Illustrations of the Botany of the Himalaya Mountains." There is also a cranium said to belong to some genus of bovine animal; another belonging to a goat resembling the markhoor (*Capra falconeri*); and a palate, in the collection of the Geological Society, doubtfully referred to a sheep (*Ovis*).

Coming to the Siwaliks it will be convenient to chronicle the fauna of both the upper and lower divisions in the same paragraphs, as a considerable number of forms are common to the two; the upper division is certainly pliocene, but it is not improbable that the lower division, as exemplified in Sind, Kach, and the regions to the north and west, may be of upper miocene age.[2] Some fossils from certain parts of the Sub-Himalayan region may however have been obtained from the lower division; while some of the mammals from Perim Island have an old facies (*Dinotherium* and *Hyotherium*), although others (the ruminants) are of a later type.

Remains of Primates are of extremely rare occurrence, and all the known species are founded upon very small and imperfect fragments of the skull or upon individual teeth. In the *Simiidæ*, the type genus *Simia* is represented by an imperfect upper canine apparently belonging to a species closely allied to the existing orang of Borneo; while a broken palate indicates a species of chimpanzee (*Troglodytes siva-*

[1] In the previous edition of this memoir these strata were referred to the pleistocene, but the author is now inclined to revert to the older view of regarding them as high up in the pliocene.

[2] Prof. Duncan (Quart. Journ. Geol. Soc. Vol. XXXVII. p. 207) includes both divisions in the pliocene, but Dr. Blanford in his latest work on Sind (Mem. Geol. Surv. Ind. Vol. XX. p. 3) refers the lower division to the upper miocene.

lensis[1]) distinguished from the existing African *T. niger* by the narrower last premolar. In the family *Cercopithecidæ*, *Semnopithecus* is represented by *S. palæindicus* which is equal in size to the existing Indian *S. entellus*, but has a less deep mandibular ramus; *Macacus*, by the small *M. sivalensis*; and *Cynocephalus*, now characteristic of Africa, by two species, one of which (*C. subhimalayanus*) agrees in dimensions with *C. anubis*, while the other (*C. falconeri*) is considerably smaller. The genus *Cynocephalus* presisted in Southern India to the pleistocene.

In the Carnivora the family *Felidæ* comprises two species of *Machærodus*,—one (*M. palæindicus*) being as large as the tiger, and the other (*M. sivalensis*) about equal in size to the jaguar. In the structure of the skull both species present characters connecting them with the American forms, but two lower premolars were developed as in *M. aphanistus* of Pikermi. *Felis* is represented by the large *F. cristata*, which is about equal in size to the tiger, but has cranial characters allying it more closely with the lion and the jaguar; and also by *F. brachygnatha*, which may be generically identical with *Cynælurus*; as well as by two other unnamed forms, of which one is allied to *F. pardus*, and the other to *F. lynx*; and also by the small *F. subhimalayana* of dimensions nearly the same as those of the living *F. bengalensis*. *Ælurogale sivalensis* is named on the evidence of a mandibular ramus from the Punjab which appears generically identical with this genus of primitive cats originally described from the Quercy phosphorites, and shows the presence of three lower premolars. *Æluropsis* is a genus peculiar to the Siwaliks, founded upon a mandible from the Punjab, apparently connecting *Machærodus* with the *Hyænidæ*, and accordingly named *Æ. annectans*. In the *Hyænidæ* a peculiar mandible from the Punjab has received the name of *Lepthyæna sivalensis*, and apparently indicates an animal connected both with *Ictitherium*, *Hyæna*, and the primitive cats. *Hyæna* itself is represented by four named species, and an unnamed form which may be specifically distinct. Two of these species—*H. colvini* and *H. felina*—are closely allied to the South African *H. crocuta* (which it will be remembered occurs in the pleistocene of Madras); and it is probable that the first of the two Siwalik species is the ancestor of the latter. *H. sivalensis* is a primitive form allied to the Indian *H. striata* (of which it may be the ancestor), but distinguished by the presence of a second lower true molar; it is closely allied to *H. græca* of Pikermi (which has been generically separated as *Hyænictis*) but has one lower premolar less. The most remarkable of the Siwalik hyænas is, however, *H. macrostoma*, which in its elongated premolars connects the more typical species with the *Viverridæ* and canoids, and is closely allied to the Pikermi *H. chæretis*, which has been generically separated by some under the name of *Lycyæna*. In the *Viverridæ* two species of Siwalik *Viverra* are known, of which *V. bakeri* is of the size of *V. zibetha*, while *V. durandi* is larger than any existing species; both forms present certain characters connecting them with *Ictitherium*; and it is not improbable that *V. bakeri* may have been the ancestor of *V. karnuliensis* of the Madras pleistocene, from which form the living Indian species may in its turn have descended. In the *Ursidæ* (which are taken to include both the bears and the dogs) the dogs are represented by *Canis cautleyi* and *C. curvipalatus*; the former being closely allied to the wolf; while the latter shows indications of affinity with the African *Otocyon*. The

[1] Originally described under the name of *Palæopithecus*.

genus *Amphicyon*, distinguished from *Canis* by the presence of an additional upper true molar, is represented by *A. palæindicus*, which is allied to *A. intermedius* of the middle miocene of Styria. The bears are represented by the genera *Ursus* and *Hyænarctos*: of the former there is a skull, without teeth, from the Sub-Himalaya which has received the name of *U. theobaldi* and appears to have been the ancestor of the living Indian *U. labiatus*, whose remains, as we have seen, occur in the pleistocene of the Karnul caves. Of *Hyænarctos* three species have been named; *H. sivalensis* has the upper molars with quadrangular crowns, and is known by a fine cranium, the half of a mandible, and some limb-bones, in the British Museum; *H. punjabiensis* is an allied form from the Punjab distinguished by the smaller size of the anterior lobe of the upper carnassial tooth; while *H. palæindicus*, known by a maxilla and mandible in the Indian Museum, is characterised by the triangular form of the crowns of the upper molars, which approach those of the European miocene genus *Dinocyon*, and not improbably by the absence of the third lower true molar. In the *Mustelidæ* the type genus *Mustela* is known by a small fragment of a mandible indicating a species of the size of *M. flavigula*. Two species of *Mellivora*, or ratel, have been described, of which the first (*M. punjabiensis*) is closely allied to the existing Indian *M. indica* and the African *M. capensis*, while the second (*M. sivalensis*) is distinguished by the different proportions of the premolars. *Mellivorodon palæindicus* is an allied form described upon the evidence of a mandibular ramus from the Punjab. Of the otters the small *Lutra palæindica* has been named from the evidence of a skull and lower jaw in the British Museum, apparently allied to *L. vulgaris*; a second species is indicated by a lower jaw from the Punjab. in the Indian Museum, which has been named *L. bathygnatha*, and indicates an animal allied to the African *L. lalandi*; while a very large form of otter named by Falconer *Enhydriodon sivalensis* has been included by the present writer in the type genus *Lutra*, with which it is connected by the large *L. campani*[1] of the middle miocene of Italy, which is evidently allied to the living Indian *L. leptonyx*. The last member of the Siwalik Carnivora belongs to the suborder Primigenia (Creodonta of Cope) and has been referred to the genus *Hyænodon*, with the specific name of *H. indicus*; this genus is indeed confined in Europe to the older tertiaries, but it appears that the South American upper tertiary form to which Bravard applied the name *Eutemnodus* is really identical.

Turning to the Ungulata we find the Proboscidean suborder very abundantly represented, species of all the known groups being present. The most specialized group is represented by *Elephas hysudricus*, of which the molars are of less complex structure than those of *E. indicus*. *E. planifrons* is remarkable for being one of the two species of true elephant in which premolars are known to have been developed. The stegodont group, peculiar to South-Eastern Asia, is represented by four species; of these the molars of *E. ganesa* and *E. insignis* appear to be indistinguishable from one another; the skull of the former, however, of which there is a magnificent specimen in the British Museum, is distinguished by its enormous tusks, and that of the latter, of which there are numerous specimens, by the pecu-

[1] This species was referred to *Enhydriodon* by Dr. Forsyth-Major, a reference which had escaped the writer's notice when describing the Siwalik form in the Palæontologia Indica.

liarly depressed form of the fronto-parietal region. Molars of *E. insignis* have been obtained from strata of probably pliocene age in Japan, and not improbably also from Java; as well as from caves in China.[1] The molars of the third species, *E. bombifrons*, are less complex than those of the preceding; and its skull has very prominent frontals. Of the fourth species, *E. clifti*, the skull is unknown, but the molars are still simpler, the intermediate ones frequently bearing only six ridges each; remains of this species have also been obtained from Burma, Japan, and China, a tooth from the latter country having been named *Stegodon sinensis;* premolars were developed in a specimen referred to this species. Eight species of mastodons are known, five belonging to the tetra-, and three to the trilophodont division of the genus. Of the former, *Mastodon latidens* approaches nearest to the stegodont group of *Elephas*, and since its molars have open valleys, and the intermediate ones occasionally carry five ridges, it affords such a complete transition between *E. clifti* and the other mastodons, as to show that the generic division between the elephants and mastodons is merely nominal. The skull of *M. latidens* is unknown; and its remains have been obtained from the Irawadi valley, the Sub-Himalaya, Sind, Perim Island, and Borneo. Closely allied to this species is one from Perim Island to which the name *M. cautleyi* has been provisionally applied, a form connecting *M. latidens* with the European *M. longirostris*. *M. punjabiensis* is a species less closely allied, and presenting some approximation in dental characters to *M. perimensis* of Perim Island, in which the columns of the molars have a tendency to an alternate arrangement, and a considerable quantity of cement is present in their valleys. The fifth tetralophodont species, *M. sivalensis*, has the molars with a distinctly alternate arrangement of the ridges, and occasionally presents a tendency to a pentalophodont formula; there is a fine skull in the British Museum, and its remains have been obtained only from the Sub-Himalaya. The skulls of the two peculiar trilophodont species are unknown, and all their remains are from the Punjab, Sind, and Perim Island. In the first, *M. falconeri*, the valleys of the molars are open, and the symphysis of the lower jaw is short, and sometimes provided with small cylindrical tusks; but in the second, *M. pandionis*;[2] the valleys are obstructed by outlying columns, and the symphysis of the lower jaw is produced into a long trough-like process, which may or may not be furnished with large, compressed tusks. The third species, of which the remains have been found only in the regions across the north-west frontier, is a variety of *Mastodon angustidens* of the middle miocene of Europe. Two species of *Dinotherium* are known, of which *D. indicum*,[3] rivals in size the European *D. giganteum*; there are several specimens of the teeth and jaws in the Indian Museum, and also in the collection of the Bombay Branch of the Royal Asiatic Society; the British Museum possesses also the cast of a cervical vertebra, part of the mandible, and some molars; remains of this species have been obtained from the Sub-Himalaya, Punjab, Perim Island, Kach, and Sind. The second species, *D. sindiense*, is only known by two specimens of a part of the man-

[1] Described under the name of *Stegodon orientalis*.

[2] The type specimens of this species were said to have been obtained from the Deccan, but appear really to have come from Sind.

[3] The form known as *D. pentapotamiæ* is now provisionally regarded as merely a small variety.

dible, one from Sind and the other (lacking the crowns of the molars) from the Punjab; both specimens are in the Indian Museum. The mandible in this species is subcylindrical in cross-section, and thereby approaches that of the mastodons.

In the Perissodactylate suborder the symphysis of a mandible from Burma has been referred to *Tapirus*, but the determination must be considered uncertain. The horses are represented by the genera *Equus* and *Hipparion;* of the former there are two species, *viz.*, *E. sivalensis*, apparently closely allied in dental characters to the pliocene European *E. stenonis*, but with a cranium resembling that of *E. hemionus;* and *E. namadicus*, in which the cranium and molars resemble those of *E. caballus*. *E. namadicus* apparently occurs only in the topmost Siwaliks. Of *Hipparion* there are apparently at least three species; *viz.*, *H. antilopinum* agreeing in size with *H. gracile*, but with only one functional digit to each foot; a second form, to which the name *H. punjabiense* has been provisionally assigned, of nearly the same dimensions, but apparently having three complete digits; and a larger species with the same number of digits known as *H. theobaldi*. A fragment of an upper jaw from Perim Island could not be satisfactorily identified with either of these three forms, and if distinct the name of *H. feddeni* has been suggested for it. The genus *Rhinoceros*, if that term be employed in its widest sense, was abundantly represented in the Siwaliks. The sole member of the atelodine group is *R. platyrhinus*, which appears closely allied to, and is perhaps the ancestor of, both the living African *R. simus* and the pleistocene *R. antiquitatis* of Northern Europe and Asia. In the rhinocerotic group *R. sivalensis* was apparently very closely allied to the living *R. sondaicus*, which it resembles in the form of its molars and the mandible. Skulls and teeth of this species are contained both in the British and Indian Museums, and its remains have been obtained from the Sub-Himalaya and Sind. The second species, *R. palæindicus*, was also unicorn, and the mandible has a pair of incisors; the upper molars are intermediate in structure between those of the living *R. sondaicus* and *R. unicornis*, and it is not improbable that the fossil species was the ancestor of the latter. The hornless rhinoceroses are represented by the gigantic *R. perimensis*, of which there is a fine cranium and numerous teeth and jaws from the Punjab in the Indian Museum, and a magnificent palate and some specimens of the mandible from Perim Island in the collection of the Bombay Branch of the Royal Asiatic Society; the British Museum also possesses a few specimens of teeth and jaws from Perim Island. *R. blanfordi* from the Bugti hills is a second hornless species closely allied to *R. incisivus* of the lower pliocene of Europe. The genus *Chalicotherium* is represented by *C. sivalense*,—a species presenting a peculiarly aborted dentition, and hence referred by some to a distinct genus, under the name of *Nestoritherium*. This species is of rare occurrence, but is known by an associated cranium and mandible, in the Museum of Mareschal College, Aberdeen, by the upper molars of each maxilla, and a mandible in the British Museum, and by a few lower molars in the Indian Museum. The latter specimens are from Sind, and the others from the Sub-Himalaya. Another species has been described from the pliocene of China, under the name of *C. sinense*.

The suborder Artiodactyla includes a very large number of both genera and species. Of the true oxen (*Bos*), three species have been named, *viz.*, *B. acutifrons*, remarkable for its enormous horns and angulated frontals; *B. planifrons*, with

shorter horns and flattened frontals, and closely allied to the European *B. taurus;* and *B. platyrhinus*, only known by the lower half of a cranium, of which the generic affinities are doubtful. The latter specimen, and the cramia of each of the preceding species, are in the Indian Museum, and came from the Sub-Himalaya. Species of *Bos* or allied genera are indicated from Perim Island by molars in the Museum of Science and Art, Dublin. One cranium from the Sub-Himalaya, in the Indian Museum, belongs to a species of *Bison*, which has been named *B. sivalensis;* it is the earliest form of the genus, and seems to have been allied to *B. europæus*. The genus *Bubalus* is represented by several species; the first of which, *B. platyceros*, is known by one cranium in the British, and another in the Indian Museum, both being from the Sub-Himalaya; the horns were stout and concave superiorly. The second species is either closely allied to, or identical with the living *B. buffelus*, which occurs in the pleistocene, if, indeed, the topmost beds of the Siwaliks in which the present form is found do not belong to the same period. There are three other species[1] of this genus more or less closely allied to the anoa (*B. depressicornis*) of Celebes; the first of which is named *B. occipitalis*, and varies considerably in the form of its horn-cores, which are sometimes nearly straight, and triangular in section, and at others curved, and pyriform in section, another variety being hornless. There are fine series of the crania of this species, both in the British and the Indian Museum, all from the Sub-Himalaya. The second species, *B. antilopinus*, is also known by several crania from the same districts. The third, *B. acuticornis*, is a long-horned form, and is represented by numerous skulls, from the Sub-Himalaya, in the British and Indian Museum. *Leptobos falconeri* is another form of bovine (in some cases hornless), of which there are several crania in the British Museum.

A remarkable hornless skull, of comparatively large size, from the Sub-Himalaya, in the collection of the British Museum, has been described under the name of *Bucapra daviesi;* this specimen comes nearest to the skulls of the goats, but has molars of a bovine type, which if found separately would certainly have been referred to some form of oxen. There is evidence of three species of true goats, the first of which, *Capra sivalensis*, is known by two crania in the British Museum from the Sub-Himalaya, and is considered to be allied to the so-called ibex of the Nilgherries (*Capra jemlaica*). The second species, *C. perimensis*, is known by a portion of a cranium in the Indian Museum, from Perim Island, and was probably allied to the living markhoor (*C. falconeri*) of the Himalaya, though the horn-cores do not show a spiral twist. The third form is unnamed, since its horn-cores, of which the Indian Museum possesses numerous specimens from the Punjab, are so like those of the markhoor, that it is difficult to point out characters of specific distinction with the materials available; it is possible that these horns may belong to older individuals of *C. perimensis*. It has been stated that a cranium from the Sub-Himalaya, which is not now forthcoming, is specifically identical with the living Himalayan ibex (*C. sibirica*), but this determination requires confirmation, although it is highly likely that the specimen may have belonged to an allied species. Another cranium, also lost, has been referred to the genus *Ovis*. Coming to the antelopes,

[1] Originally described under the names of *Hemibos, Amphibos, Probubalus*, and *Peribos;* the synonymy, which is much involved, will be found in part ii of the writer's 'Catalogue of Fossil Mammalia in the British Museum.'

an imperfect cranium from Perim Island belongs to the existing African strepsicerine section and has been named *Strepsiceros* (?) *falconeri*[1]; while maxillæ from the Punjab have been provisionally referred to *Oreas* under the name of *O.* (?) *latidens.* The existing Indian genus *Boselaphus* is indicated by numerous jaws, teeth, and limb-bones, but none of these specimens afford characters sufficient to determine whether the Siwalik nilghai is distinct from the Narbada *B. namadicus.* The African genus *Hippotragus* is represented by *H. sivalensis,* of which the British Museum has a fairly perfect cranium; while the more widely spread *Gazella* is known by *G. porrecticornis,* and not improbably by a smaller unnamed species from the Punjab. Two species of antelope, in which the females were unprovided with horns as in the existing African genus *Cobus,* have been provisionally referred to that genus under the names of *C.* (?) *palæindicus* and *C.* (?) *patulicornis,* and in any case indicate closely allied forms. A small antelope closely resembling in general characters the existing Indian *Tetraceros quadricornis* has been named *T. daviesi,* and apparently differs from the former chiefly in the characters of the upper premolars; while it has been suggested that a fragment of the maxilla of a still smaller antelope may possibly belong to the African genus *Cephalopus.* *Alcelaphus palæindicus* is a large antelope presenting cranial characters intermediate between those of the hartebeest and the blessbock.

The family *Giraffidæ* is taken to include *Sivatherium* and its allies, and is thus strongly represented in the Siwaliks. There has been considerable discussion as to the serial position of the following forms; *Helladotherium,* with the giraffe, being classed by some with the deer, while *Sivatherium* and the two succeeding genera are grouped with the antelopes. The resemblance of the teeth and bones of all these animals is, however, so close that it seems preferable to class them all together in one large family, connecting the deer with the antelopes. The first genus is the well-known *Sivatherium,* represented by the one species *S. giganteum,* in which the skull was furnished with two pairs of horns. Remains of this species have been obtained only from the Sub-Himalaya eastward of the Punjab, and of these the British Museum possesses a magnificent series. The second genus *Bramatherium* is known by *B. perimense,* of which the cranium, teeth, mandible, and some of the limb-bones are known; this species carried a pair of horns above the occiput, and a large common horn-base on the frontals. Its remains have been obtained from Perim Island, and the one known cranium is in the Museum of the Royal College of Surgeons; upper molars are in the British Museum, two fragments of the mandible in the Indian Museum, and another, with the last true molar, in the Museum of Science and Art, Dublin. Of *Hydaspitherium,* there are two species, of which *H. megacephalum* is known by a cranium and a large series of teeth and bones; all from the Punjab, and preserved in the Indian Museum; it carried a massive common horn-base above the occiput from which the horns took their origin. The second species, *H. grande,* was larger and is only known by the upper molars and the mandible; all of which are from the Punjab, and are now in the Indian Museum. It is probable that a cervical vertebra from Beluchistan, in the collection of the Geological Society, belongs to one of the above forms. A species of *Hel-*

[1] Teeth formerly provisionally referred to *Palæcryx* apparently belong either to this or a allied species.

ladotherium, apparently indistinguishable from *H. duvernoyi* of Europe and Persia, is represented by a single cranium in the British Museum. The last of the four genera peculiar to the Siwaliks is *Vishnutherium*, which is known by a part of the mandible from Burma, and probably by two upper molars and some bones from the Punjab, all of which are in the Indian Museum. It seems to come the nearest of the four to the giraffe, and has been named *V. iravaticum*. The one species of *Giraffa* (*G. sivalensis*) appears closely allied to the existing giraffe, and also to the extinct *G. attica* of Greece and Persia; it has been found in the Siwalik hills, the Punjab, and Perim Island.

In the *Cervidæ* three specific names have been applied to forms referred to *Cervus*, but in one instance the generic reference may be incorrect; *C. sivalensis* has been assigned to the rucervine group characteristic of South-Eastern Asia, the antlers probably belonging to it presenting characters intermediate between those of *C. duvaucelli* and *C. eldi*. One upper molar from the Punjab has been provisionally referred to *Moschus;* while another molar from the same region indicates a species of *Palæomeryx* (*P. sivalensis*) equal in size to the large *P. bojani* of the middle miocene of Europe. There are two species of *Camelidæ*, both belonging to the type genus, and respectively named *Camelus sivalensis* and *C. antiquus;* in the lower true molars of both species there is a vertical ridge now found only in the American *Auchenia*, and their cervical vertebræ are intermediate in structure between those of the latter and those of the existing species of *Camelus*. In the *Tragulidæ* a species of *Tragulus* has been named *T. sivalensis* on the evidence of an upper molar from the Punjab; and *Dorcatherium* (which is probably identical with the existing African *Hyomoschus*) is represented by the two species *D. majus* and *D. minus*. *Chæromeryx silistrensis* is a peculiar tetracuspidate brachydont form provisionally referred to the *Dichodontidæ*, which has been obtained both from Sylhet and Sind.[1] A single upper molar from Sind, in the Indian Museum, apparently belongs to the North American family *Oreodontidæ*, and has been provisionally referred to the genus *Agriochærus;* it seems very close to *A. latifrons*. The name *Hemimeryx blanfordi* has been applied to a large selenodont upper molar from Sind, which appears closely allied to one species of *Merycopotamus*, and may eventually prove to be generically identical. Of *Merycopotamus* itself (which on account of the presence of only four cusps to the upper true molars is made the type of a distinct family, although included by some writers in the *Anthracotheriidæ*) there are three species, of which the typical *M. sivalensis* is the largest. The smaller *M. nanus* is readily distinguished by its relatively shorter jaws; while the still smaller *M. pusillus* (known only by a single upper molar from Kushalgarh in the Punjab) presents a difference in the structure of the upper molars, and apparently thereby approximates to the *Dichodontidæ*.

Of the selenodont pig-like animals, with five columns on the upper molars, forming the family *Anthracotheriidæ*, we have two named species of *Anthracotherium*, and two of *Hyopotamus*. Of the former, one species (*A. silistrense*) is of small size, and is known by three upper molars, and parts of the mandible; these specimens have been obtained from near Sylhet, the Punjab, and Sind, and most of them are in the Indian Museum. The second species, *A. hyopotamoides*, is of very large size, and

[1] The Sind form was originally separated under the name of *Sivameryx sindiensis*.

is known by wo upper molars in the Indian Museum, from the Bugti hills, to the north of Sind; some imperfect specimens of the mandible may also belong to this species. In addition to these named forms there are also two fragments of mandibular rami in the British Museum from the Siwalik hills, which apparently indicate the occurrence of two other species intermediate in size between *A. silistrense* and *A. hyopotamoides*. Of *Hyopotamus*, a small species, *H. palæindicus*, is known by several teeth and one lower jaw, from Sind, in the Indian Museum; the molars of this species have very low crowns and differ somewhat in structure from those of all the European forms. The second species, *H. giganteus*, is known by two upper molars, and by some specimens of the mandible from the Bugti hills, now in the Indian Museum; the upper tooth much resembles that of *Anthracotherium hyopotamoides*, and with that species forms a complete transition between *Anthracotherium* and *Hyopotamus*. A peculiar form of pig-like animal from the Sub-Himalaya known as *Tetraconodon magnus* is apparently allied to *Elotherium*, but distinguished by the presence of a hind talon to the last lower molar, and by the enormous size of the premolars. The former character approximates this genus to the *Suidæ*, and tends to indicate the advisibility of retaining the family *Chæropotamidæ* for *Chæropotamus* and *Elotherium*, rather than of including these genera in the *Anthracotheriidæ*. In the *Suidæ*, *Hyotherium* is represented by *H. sindiense* of the lower Siwaliks of Sind, and *H. perimense* [1] of Perim Island; the former being apparently allied to *H. sæmmeringi* of the middle-miocene of Styria and other parts of Europe, while the latter is distinguished by the great relative width of the lower true molars. *Hippohyus* is a peculiar Siwalik form apparently allied to *Hyotherium*, in which the columns of the cheek-teeth have attained an excessive complexity of structure; it is represented by the typical *H. sivalensis*, and not improbably by a second unnamed species. *Sanitherium schlagintweiti* is a smaller form apparently allied to the present group, and known only by a few fagments of the mandible obtained from Kushalgarh. *Sus* is represented by five named species; among which *S. titan* is the largest pig known in the world; its molars are of a simple structure, the talon of the last one being of small size. *S. giganteus* is a somewhat smaller species also having simple molars, in which the cranium approximates to that of *S. vittatus;* the mandible provisionally referred to this species is characterized by the unusual width of the premolars. *S. falconeri* is a species usually somewhat larger than the existing *S. cristatus*, and characterised by the extreme complexity of the true molars, especially the last, in which respect this species, in common wtth *S. phacochæroides* of the pliocene of Algeria, makes a decided approach towards *Phacochærus;* and it is not improbable, as mentioned above, that *S. cristatus* is descended from it: the elongated facial portion of the cranium recalls that of *S. barbatus* of Borneo. *S. hysudricus* is a small species with simple molars, very closely allied to *S. palæochærus* of the European lower pliocene; while *S. punjabiensis* is of still smaller dimensions, and was not improbably the ancestor of the pigmy *S. salvanius* of the Nipal terai. Some unnamed specimens may indicate a sixth species of the genus. The genus *Listriodon*, the type of a separate family, is represented by *L. pentapotamiæ* and *L. theobaldi*, the former being known by several molars, and the latter only by one molar of small size. All these teeth were obtained from the

1. Quart. Journ. Geol. Soc. Vol. XLIII. p. 19 (1887).

Punjab, and are in the Indian Museum. Finally, in the *Hippopotamidæ* there are two species of *Hippopotamus*, both of which were furnished with three pairs of incisors; *H. sivalensis* was of comparatively large size, while the Burmese *H. iravaticus* was considerably smaller and has a relatively longer mandibular symphysis.

The remaining orders of the Mammalia are only represented by a few species of rodents, and by one edentate. Of the former, a species of *Nesokia*, apparently allied to the existing Indian *N. hardwickei*, is indicated by a mandibular ramus from the Sub-Himalaya. A species of bambu-rat (*Rhizomys sivalensis*) has been determined on the evidence of specimens of the mandible. A porcupine (*Hystrix sivalensis*) is known by a part of a young cranium and the mandible, the former, which is from the Siwalik Hills, being in the British and the latter, which is from the Punjab, in the Indan Museum; while a species of *Lepus* is indicated by a small fragment of a mandible in the British Museum. The Edentata are known only by one phalangeal bone from Sind which was originally named *Manis sindiensis*, but subsequently referred to *Macrotherium*. This bone apparently indicates a species intermediate between typical species of the latter genus and *Manis*, and it had been suggested that *Manis gigantea* may have descended from this form.

Miocene.—The only determined undoubted miocene mammal is a small rhinoceros from the Gaj beds of Sind, which has been regarded as a variety of *R. sivalensis*, and named *var. gajensis*; it is, however, quite probable that it may be specifically distinct.

Eocene.—No traces of mammals have yet been detected below the eocene, and in that formation only some very fragmentary bones have been obtained from the Punjab. The determinable bones consist of the distal portions of the femur and the metatarsus of a perissodactyle animal, allied to, if not identical with, *Palæotherium*; and the astragalus of an artiodactyle. The latter was obtained above the nummulitic clays of Fatehjang, and apparently belonged to an animal, in which the navicular and cuboid elements of the tarsus were united. These specimens are in the Indian Museum.

CLASS II.—AVES.

Pleistocene.—The Karnul caves have yielded a small number of bird-remains all of which have been referred to existing Indian species. These comprise *Neophron percnopterus*; a smaller accipitrine bird which may be a *Milvus* or a *Circus*; the Ceylon fish-owl (*Ketupa ceylonensis*); an eagle-owl, *Bubo coromandus*; two species of francolin, *Francolinus pictus*, and *F. pondicerianus*; a crane which is very probably *Grus communis*; and the black-headed ibis (*Ibis melanocephala*).

Pliocene.—Remains of birds have hitherto been found only in the upper Sub-Himalayan Siwaliks, and their numbers are still very small. Some of these remains are in the British and others in the Indian Museum. Among the Carinatæ, a tarso-metatarsus has been considered to belong to a cormorant, and is provisionally referred to the genus *Phalacrocorax*. A species of pelican (*Pelecanus cautleyi*), somewhat smaller than the living Indian *P. mitratus*, is indicated by a fragment of the ulna; while another fragment of the homologous bone has been referred to a second species, under the name of *P. sivalensis*, but there is some doubt whether the generic determination is correct. A species of adjutant-stork, which appears to have had

considerable variations in size, has been named *Leptoptilus falconeri*; while a cervical vertebra from the Punjab indicates another genus of the same group. Another cervical vertebra from the same district has been provisionally referred to *Mergus*. The Ratitæ appear to have been represented by two species, one of which was a true ostrich (*Struthio asiaticus*[1]), and is known by several bones of the leg and foot, and some cervical vertebræ; while the other was a three-toed form of which the genus has not been determined.

CLASS III.—REPTILIA.

I.—TERTIARY.

Pleistocene.—The reptilian remains from the Karnul caves comprise a tooth of a species of *Crocodilus*; numerous bones of the existing Madras monitor (*Varanus dracæna*); and, in the *Ophidia*, vertebræ of *Python molurus*, of the cobra (*Naia tripudians*), and of a large snake provisionally identified with *Ptyas mucosus*. Some other small ophidian, as well as chelonian, remains have not been even generically identified.

The reptiles of the older pleistocene are still very imperfectly known, but it is probable that they all belong to living Indian species. From both the Jamna and Narbada beds specifically indeterminable remains of crocodiles have been obtained. A complete specimen of the carapace of *Pangshura flaviventris*[2] from the Narbada is in the Indian Museum, and serves to connect the living with the Siwalik form, and also shows that the range of the species once extended over the greater part of India; a less perfect specimen in the same Museum may also belong to this species. A portion of the plastron of a *Batagur* from the Narbada valley has been provisionally referred to *B. dhongoka*, now found in that river. A fragment of the carapace of a *Trionyx*, from the same deposits, probably belonged to *T. gangeticus*, and a cranium in the British Museum gives more certain evidence of the occurrence of that species.

Pliocene and (?) upper miocene.—The Chelonia of the Siwaliks although still imperfectly known, are represented by a considerable number of forms. In the *Testudinidæ* the gigantic *Colossochelys atlas* is the largest of all known forms; it is distinguished from *Testudo* by the non-union of the pygal plates[3] of the carapace, and by the production of the plastron anteriorly into a pair of cornua, supported on the ventral aspect by a strong triangular keel on which the gular plates are borne; the length of the restored carapace in a straight line is 8 feet 4 inches. Four other forms of gigantic land-tortoises are indicated by remains which are not sufficiently perfect to admit of generic determination. The first of these species is about one-half larger than the living *Testudo elephantina* of Aldabra, and has an epiplastron intermediate in structure between that of *Colossochelys atlas* and that of the existing Indian *Manuria emys*. The second, which may be identical with the form to which the name *Cautleya annuliger* has been applied, is about one-fourth larger than *T. elephan-*

[1] A limb-bone of this species, and a specimen which is apparently not avian at all, were made the types of the genus *Megaloscelornis*. Other bones were referred to *Dromæus* but these also turn out not to be avian.

[2] Originally described as *P. tectum*.

[3] The term plate is applied to the horny epidermal covering, and scute to the subjacent bony layer.

tina. The third is of nearly equal dimensions, but has a very different epiplastron; while the fourth is considerably smaller, and appears more nearly allied to the existing land-tortoises of India and Burma. In the *Emydidæ*, *Clemmys* is represented by several forms, six of which have received distinct specific names. Of these *C. sivalensis* is allied to the existing *C. crassicollis* of India and the neighbouring regions, but has no nuchal plate; *C. hydaspica* is an allied form in which the nuchal plate is present; while a third member of the same group is found in *C. theobaldi* which has an unusually depressed carapace, with a first vertebral plate of very remarkable shape. *C. punjabiensis* is a form with a bell-shaped first vertebral plate, in which respect it resembles certain North American species of the genus; its hinder vetebrals have not the 'mushroom-shape,' characteristic of the three preceding species. A fifth unnamed species comes so close to the existing Indian *C. trijuga*, that it may be pretty safely regarded as the ancestor of that species, if indeed it be not identical. From Perim Island a shell with quadrangular vertebral plates has received the name of *C. watsoni* [1]; while *C. palæindica* of the Siwalik hills appears closely allied to the tricarinate *C. hamiltoni* of India, of which it may have been the ancestor. An unnamed form from Perim Island may perhaps indicate an eighth species of the genus. The characteristic Indian genus *Pangshura* is represented by a form provisionally identified with the existing *P. flaviventris*, which, as we have seen, also occurs in the pleistocene; and by an unnamed species apparently more nearly allied to *P. tectum* and *P. tentoria*. Of *Batagur*, a genus confined to the Oriental region, there are four named species. Of these *B. falconeri* is regarded as the ancestor of the Indian *B. thurgi*; *B. bakeri* is equally closely allied to the existing *B. kachuga*; *B. durandi* shows a strong resemblance to *B. dhongoka*; while *B. cautleyi* presents affinity to *B. affinis* and *B. pictus*, respectively of the Malayan peninsula and Borneo. A generically undetermined nuchal scute from the Punjab may belong to a member of the genus *Geoemyda*. In the *Trionychidæ*, *Emyda* is represented by the existing Indian *E. vittata*, and also by three extinct species respectively named *E. lineata*, *E. sivalensis*, and *E. palæindica*. The three latter differ from existing species in the structure of the nuchal scute, and the last two are of comparatively large size. *Trionyx* was probably represented by several species, but none of the specimens yet obtained have afforded satisfactory characters for specific diagnosis. Lastly, the peculiar Indian genus *Chitra* is represented by the existing *C. indica*, which is the only known species.

In the Crocodilia, *Crocodilus sivalensis* is very closely allied to the existing Indian *C. palustris*; while *C. palæindicus* of Perim Island is another member of the same group distinguished by its convex facial profile. The gharials are represented by the existing *Garialis gangeticus*; and by an allied form known as *G. hysudricus*, which is distinguished by the form of the rostrum, and probably also by that of the cranium proper. *G. curvirostris* from the lower Siwaliks of Sind is a very distinct form characterised by the non-eversion of the anterior border of the orbit, and probably allied to certain upper cretaceous gharials of North America which have been generically separated under the name of *Holops*. *G. leptodus* is known only by the rostrum, which presents certain characters approximating it to *Tomi-*

[1] Quart. Journ. Geol. Soc. Vol. XLII. p. 540 (1886).

stoma. In *G. pachyrhynchus* of the lower Siwaliks of Sind we have a gigantic species provisionally referred to the type genus presenting certain marked peculiarities in the relations of the anterior teeth and their pits. Finally another gigantic species from the upper Siwaliks has been made the type of the genus *Rhamphosuchus*, with the specific affix of *crassidens*, and indicates a gharialoid presenting features in the relations of the upper and lower dentition now found only in the short-jawed alligatoroid members of the order.

The Lacertilia are only known by the gigantic *Varanus sivalensis*, which is estimated to have attained a length of eleven feet. The group appears to be an old one, as it is represented by the closely allied, if not generically identical, *Palæovaranus* of the Quercy phosphorites.

The only remains of *Ophidia* hitherto obtained from the Siwaliks are vertebræ of the genus *Python* from the Punjab and Sind. Some of these specimens have been provisionally identified with the existing Indian *P. molurus*, while others may indicate a distinct species. A python from the Quercy phosphorites, originally named *Python cadurcensis*, but regarded by some as generically distinct and therefore named *Palæopython*, carries back the origin of these huge serpents to a remote epoch.

Eocene.—The only specifically determined eocene reptile may be referred to the genus *Platemys*, under the name *P. leithi*. The specimen on which this determination rests is a carapace from the inter-trappeans of Bombay. The genus *Platemys* belongs to the *Chelydidæ*, and, although occurring in the Purbeck and lower eocene of England, is now confined to South America; the section or sub-order (*Pleurodira*) of which that family is a member being characteristic at the present day of the southern hemisphere. From the nummulitics of the Punjab numerous fragmentary remains of crocodilians have been obtained, but are in too imperfect condition for determination. Remains of large chelonians have recently been obtained from below the coal-beds at Nila in the Salt-range, which are apparently transitional between the eocene and cretaceous. These specimens apparently belong to two genera; and for one which presents the peculiar feature of having the carapace covered with horny plates, while the plastron is pitted as in the *Trionychidæ*, the name of *Hemichelys warthi* is proposed; like *Platemys*, it belongs to the *Pleurodira*.

II. MESOZOIC AND PALÆOZOIC.

Cretaceous.—From the Arialur group (upper cretaceous) of the Trichinopoli series, and probably from the Lameta group (higher cretaceous), there have been obtained a few teeth of species of *Megalosaurus*, a genus whose range in England extends from the jurassic to the wealden, but is also found in the Maestricht beds of the Continent; the one tooth of the Indian form now forthcoming is in the Indian Museum. From the Lameta group there have also been obtained the remains of another genus of gigantic dinosaur, to which the name *Titanosaurus* has been assigned, which was represented by two species—*T. indicus* and *T. blanfordi*; the

[1] Referred by Gray ('Ann. Mag. Nat. Hist.' ser. 4, Vol. VIII., p. 339) to *Hydraspis*, which is now usually included in *Platemys*. The species was originally described by Carter as a *Testudo*.

former characterised by the centra of the caudal vertebræ being compressed, while in the latter they are sub-cylindrical. Numerous vertebræ, chiefly caudal, and a huge femur, nearly 4 feet in length, are preserved in the Indian Museum, and there is a cast of one of the former, belonging to *T. indicus*, in the British Museum. These forms, which have hitherto been regarded as allied to *Ceteosaurus* of the European wealden, but are referred to a separate family, appear much more closely related with *Ornithopsis* of the wealden, since a caudal vertebra from the Isle of Wight preserved in the British Museum, agrees very closely with the vertebræ of *T. blanfordi*, and agrees in relative size with *Ornithopsis*, of which the caudal vertebræ have been hitherto unknown. It may eventually prove that *T. blanfordi* is generically distinct from *T. indicus*. A few bones in the Indian Museum indicate a smaller undetermined reptile from the Lametas. The Chelonia are known in the cretaceous by some broken plates, in the collection of the Indian Museum, obtained from the Lametas, from the infra-trappeans of Rajamahendri (Rajamundry), and from the upper cretaceous of Sind. The Crocodilia are represented by one amphicœlian species, apparently allied to *Suchosaurus* of the English wealden, of which some vertebræ have been obtained from the upper cretaceous of Sind, and are now in the Indian Museum. A large species of *Ichthyosaurus* named *I. indicus* is known solely by a few vertebræ obtained from the Utatur group (middle cretaceous) of the Trichinopoli series, and now in the Indian Museum; the range of the genus in Europe is from the lias to the chalk.

Gondwana system.—The exact identification of the different members of the great freshwater Gondwana system of Peninsular India with European horizons must be regarded as still unsettled, although it is probable that the fossiliferous beds range from the jura to the permian.[1] From the Chari group of the jura of Kach there has been obtained a single vertebra, with an amphicœlian centrum, of which the affinities have not yet been determined, but which may be crocodilian[2]; and from the Umia group of the same, a fragment of the mandible of a *Plesiosaurus*, described as *P. indicus*; the affinities of the latter form cannot be fully determined from the specimen.

The Maleri group, whose fauna agrees with that of the upper trias of Europe, has yielded the primitive crocodilian *Parasuchus hislopi*, which is apparently allied to *Stagonolepis* of the Elgin sandstone, and is the type of the suborder Parasuchia; *Hyperodapedon huxleyi*, differing from the triassic European *H. gordoni* by the arrangement of the palato-maxillary teeth, and apparently by the presence of lateral teeth on the mandible; and a dinosaur apparently allied to the European triassic genus *Thecodontosaurus*. The Tiki group in South Rewah, which is provisionally

[1] In dealing with the vertebrates of certain Gondwana groups, I have shown that the evidence taken alone would indicate the following homotaxy of certain groups, *viz.*:—

Low. Jura.:—Kota. } (Jabalpur and Rajmahal.)
Up. Trias.:—Maleri. }
Low. Trias.:—Panchet.
Up. Permian:—Bijori and Mangli (Upp. Damuda).

This would indicate that the Barakars (Low. Damuda) correspond either with the lower permian or the upper carboniferous, and the Talchirs either with the upper or lower carboniferous. See Appendix, and 'Records', Vol. XIX, pp. 133-34 (1886).

[2] It has been suggested that this form may be *Parasuchus*; but the horizon renders this improbable.

correlated with the Maleri horizon has yielded the same rhynchocephalian and dinosaurian remains, but the crocodilian of the latter group is replaced by the European genus *Belodon*, so characteristic of the upper trias (keuper) of Germany. The oldest reptiles hitherto found in India occur near Ranigunj in lower Bengal, in the Panchet group of the Gondwanas, of which the vertebrate fauna has a lower triassic facies. The remains of a species of *Dicynodon*, belonging to the *Ptychognathine* group, are of comparatively common occurrence in the coarse Panchet sandstone, and have been described as *D. orientalis*. Other remains seem to indicate a second and larger species of the genus. The suborder[1] of reptiles to which *Dicynodon* belongs is characteristic of the reputed trias of India, Russia, and Africa, and attained its fullest development in the latter country. The remains of the Indian forms all occur over a very small area in one thin seam of the Panchets. The dinosaur has been named *Epicampodon*[2] *indicus*, and is the sole representative of the genus; it is known merely by two minute, compressed, and trenchant teeth, with serrated edges like those of *Megalosaurus*, and implanted in distinct sockets. The above specimens are in the Indian Museum.

CLASS IV.—AMPHIBIA.

I.—TERTIARY AND POST-TERTIARY.

Pleistocene.—Remains of a large *Bufo*, probably identical with the existing Indian *B. melanostictus*, have been obtained from the Karnul caves in Madras.

Eocene.—In the eocene of Bombay there occur numerous remains of a small frog, belonging to the genus *Oxyglossus*, now living in China, Siam, and possibly India; the fossil species is extinct, and is known as *O. pusillus:* remains of a larger, but undetermined, frog are also indicated.

II.—MESOZOIC AND PALÆOZOIC.

Gondwana system.—The Denwa group of the Satpura district, which is probably not far removed in time from the Maleri horizon, has yielded the right supratemporal bone of a large species of *Mastodonsaurus* closely allied to *M. giganteus* of the upper and middle trias (keuper and muschelkalk) of Europe. Remains of another large labyrinthodont, apparently allied to the upper triassic (keuper) *Metopias* and *Capitosaurus*, have been obtained from the Maleri and Tiki (South Rewah) groups; while the former group has also yielded fragments of a *Pachygonia* which may be specifically identical with the Panchet form.

From the Panchet group three genera of slender-jawed labyrinthodonts allied to those of the European lower trias are known. The first of these, *Pachygonia*, has only the one species *P. incurvata*, and is known by the greater part of the mandible, and a fragment of the cranium. The marking of the former is like that of *Mastodonsaurus*. The second genus, *Gonioglyptus*, has two species, the smaller known as *G. longirostris* and the larger as *G. huxleyi;* it is considered to be closely allied to *Trematosaurus* of the bunter-sandstone of Germany. The third genus is

[1] The ordinal term Anomodontia is here used in a wide sense to embrace the Dicynodontia, Rhynchocephalia, Theriodontia, &c., which are ranked as suborders.

[2] Originally described as *Ankistrodon*—a name preoccupied by a genus of Pisces (*Ancistrodon*).

known only by a single fragment of a mandible, to which the name *Glyptognathus fragilis* has been applied. These three genera are peculiar to India, and all their remains are exhibited in the Indian Museum; the two former belonging to the section Euglypta. From the Mangli beds another peculiar genus of labyrinthodont has been obtained, and is represented by a single skull in the collection of the Geological Society, to which the name *Brachyops laticeps* has been applied. This genus is allied to *Rhinosaurus* from the jurassic of Europe, to *Micropholis* of the Karoo system of Africa, and to *Bothriceps* of the reputed trias of Australia, and with them constitutes the section Brachyopina. The oldest Indian labyrinthodont at present known is represented by the greater portion of a skeleton obtained from the Bijori group, and has been referred to the *Archegosauridæ* under the name of *Gondwanosaurus bijoriensis*; it presents the peculiar type of vertebral structure to which Professor Cope has applied the name rhachitomous, and is of great interest as showing the wide distribution of these primitive forms in this early period of the world's history.

CLASS V.—PISCES.

I.—TERTIARY.

Pliocene and (?) upper miocene.—With one exception all the remains of Siwalik fishes have been obtained from the upper division of the series. Teeth of a species of *Carcharias* apparently allied to the existing Indian *C. glaucus* and *C. gangeticus* occur sparingly in the Siwaliks of the Punjab; and it is interesting to notice that the latter shark which frequently ascends a considerable distance up tidal rivers, is found living in inland lakes in the Fiji islands. The large-toothed *Carcharodon* is represented by a single tooth from the Siwaliks of lower Burma. In the Teleostei, as might have been expected, nearly all the Siwalik forms belong to the families *Ophiocephalidæ* and *Siluridæ*, which are now so abundantly represented in the freshwaters of India. Of the former family the type genus *Ophiocephalus* is represented by two species, one considerably larger than the other. This genus is mainly characteristic of the Oriental region, although one or two species occur in Africa, and no other fossil forms are known. In the *Siluridæ* the genus *Clarias*, which is confined to the Oriental region and Africa, is represented by *C. falconeri*; while one species of the allied African genus *Heterobranchus* has been described under the name of *H. palæindicus*. An imperfect cranium from the Punjab has been provisionally referred to the genus *Chrysichthys*, now characteristic of tropical Africa, under the name of *C. theobaldi*; and if rightly determined affords additional evidence of the African affinities of the Siwalik fish-fauna, so strongly exemplified by the occurrence of *Heterobranchus*. The existing *Macrones aor* of the Indian and Burmese rivers has existed there since the Siwalik period; while the characteristic Oriental genus *Rita* was represented by a large species from the Punjab to which the name *R. grandiscutata* has been applied. Of the widely-distributed genus *Arius* there is evidence of two species; one being very large and apparently allied to the existing *A. latiscutatus* of West Africa; while the other is smaller, and its generic reference provisional; the latter is known only by palatines from the Punjab and Sind. Finally more numerous remains belonging to the huge *Bagarius yarrelli* now inhabiting the larger rivers of India and Java have been obtained from the typical Siwalik hills. The genus *Bagarius* is a comparatively old one, since remains

from the older tertiaries of Padang in Sumatra have been described under the name of *B. gigas.* The last Siwalik fish belongs to the family *Cyprinodontidæ*, but its generic position has not yet been determined; the one specimen is preserved in the Museum of Science and Art, Dublin.

Eocene.—From the eocene of the Andaman Islands and Ramri Island on the Arakan coast there have been obtained two teeth of a large *Diodon*, named *D. foleyi;* and from the occurrence of *D. hystrix* off these coasts at the present time, it may be assumed that the genus has lived there since the eocene. Remains of this genus have been obtained from the miocene of Malta and other parts of Europe. Undetermined cycloid scales have been obtained from the eocene of Thyetmyo in Burma. From the eocene of Kach the dental plate of a species of eagle-ray has received the name of *Myliobatis curvipalatus;* while from the neighbourhood of Kohat, in the Punjab, a single incisor of a sparoid fish, named *Capitodus indicus*, has been obtained. This genus was previously known only from the miocene of the Vienna basin and Silesia, and is allied to the living *Sargus*. All the above specimens of teeth are in the collection of the Indian Museum. A fragment of chert from Sind, which is of eocene age, in the British Museum (No. 23284), bears the impress of part of the cranial rostrum of a sword-fish of the genus *Cœlorhynchus*, which is found in the Bracklesham beds and the London-clay of Sheppey. The above-mentioned bed in the Salt-range from which the Chelonians were obtained, has also yielded some undescribed fish-teeth which are said to belong to the genera *Lamna, Otodus, Hemipristis, and Capitodus.*

II.—Mesozoic and Palæozoic.

Cretaceous.—A few remains of fishes have been obtained from the higher cretaceous Lameta group, but are not determined, though it has been suggested that some of them may belong to the genus *Sphyrænodus*, of the cretaceous of Europe. From the three groups of the middle and upper cretaceous Trichinopoli series the remains of several species of sharks have been obtained; these comprise the genera *Corax* (probably not really different from *Carcharias*), *Lamna* (including *Oxyrhina*), *Odontaspis*, and *Otodus;* all these genera occur in the cretaceous of Europe, the species *Corax pristodontus* being common to the two regions. The widely-distributed upper cretaceous *Ptychodus latissimus* has left a few remains; and it may be well to observe that the genus *Ptychodus*, which has been usually referred to the cestraciont sharks, appears really to be a ray.[1] One fragment indicates a ganoid which has been provisionally identified with the European genus *Pycnodus;* while another member of the same order is referred to *Sphærodus* with the name of *S. rugulosus*. The only known teleostean fish from this formation belongs to the European cretaceous genus *Enchodus*, and has received the name *E. serratus;* the genus is now referred to the family *Trichiuridæ*, of which the scabbard-fish (*Lepidopus*) is a well-known example.

Gondwana system.—From the Kota group, whose fauna presents a decided liassic facies, nine species of ganoids have been determined; many of them on nearly complete specimens. The *Dapedidæ*[2] are represented by *Tetragonolepis* (three

[1] See a paper by Mr. A. Smith-Woodward in the Quart. Journ. Geol. Soc. Vol. XLIII.
[2] *Stylodontidæ* of Günther.

species) and the closely allied *Dapedius* (one species); both genera being in Europe exclusively jurassic, and especially characteristic of the lias. The other family is the *Lepidotidæ*,[1] of which there are five species belonging to the type genus *Lepidotus*, which ranges from the lias to the cretaceous, and apparently survived into the eocene, if the species from that formation should not prove to be a *Lepidosteus*. The remaining ganoid is not generically determined. In the Maleri group, the fauna of which shows an upper triassic facies, three species of the genus *Ceratodus* have been determined, and respectively named *C. hislopianus*, *C. hunterianus*, and *C. virapa*; the latter being considered closely allied to *C. polymorphus* of the upper trias (rhætic) of Bristol. At the present day the genus inhabits the rivers of Queensland, and in Europe is found fossil from the upper trias (keuper) to the jura. The specimens are in the Indian Museum.

Productus-limestone.—The earliest Indian Vertebrata of which there is any record are known merely by a few specimens of teeth and spines obtained from the palæozoic rocks of the Salt-range in the Punjab. The system from which these remains were obtained is termed the 'Productus-Limestone,' and is considered to correspond to the permian and upper carboniferous of Europe. A peculiar genus of ganoid is described, upon the evidence of a single tooth, under the name of *Sigmodus dubius*; this tooth being of an elongated conical form and much resembling the teeth of certain saurians. Other small teeth have been doubtfully referred to the ganoid genus *Saurichthys*, with the name of *S.* (?) *indicus*; the genus belongs to the same family as *Holoptychius*, and is characteristic of the devonian and carboniferous of Europe. Of the cochliodonts, referred by Günther to the *Cestraciontidæ*, there are two peculiar genera, each represented by a single species, namely, *Pœcilodus paradoxus* and *Psephodus indicus*; the tooth of the former is of the flattened cestraciont type. Of other Selachoidei with crushing teeth, six genera have been named, some from the evidence of teeth, and others from spines; but in view of certain modern discoveries, it is not impossible that in some cases distinct genera have been formed from the different remains of the same animal. Of these the new genus *Helodopsis*, allied to the European *Helodus*, has been formed for the reception of two teeth, which have been referred to distinct species under the respective names of *H. elongata* and *H. abbreviata*. A fragmental tooth, too imperfect for specific determination, has been referred to the common European devonian and carboniferous genus *Psammodus*.[2] A fourth tooth, under the name of *P. indicus*, is referred to the European genus *Petalorhyncus*, which is very doubtfully separated from *Petalodus*. Teeth of two species of *Acrodus* have also been described, to one of which the name *A. flemingi* has been applied. Of the spines, three specimens are referred to the genus *Xystracanthus*, of the carboniferous of North America, under the name of *X. gracilis*, *X. major*, and *X. minor*; the possibility of these specimens belonging to some species of *Helodopsis* is, however, suggested. A fourth spine is referred to a genus, under the name of *Thaumatacanthus blanfordi*. As far as the evidence of these fishes goes, it is apparent that sharks with crushing teeth were the dominant forms in the Indian carboniferous seas, as well as in those of Europe and America. Most of the specimens noticed above are in the collection of the Indian Museum.

[1] *Sphærodontidæ* of Günther.

[2] This genus may eventually prove to be a ray.

SYSTEMATIC CHRONOLOGICAL LIST OF SPECIES.

I. TERTIARY AND POST-TERTIARY.

1. PLEISTOCENE AND (?) LATER BEDS.

a. Turbary and alluvium of Madras,[1] *Assam, etc.*

MAMMALIA .	. PRIMATES . .	† Macacus *sp.* (*cf.* rhesus [*F. Cuv.*]).
		sp. (*cf.* sinicus [Linn.])
	UNGULATA . .	Elephas indicus, *Linn.*
		† Rhinoceros unicornis, *Linn.*
		† Sus cristatus, *Wagner.*

b. Caverns of the Karnul district, Madras.

,,	. PRIMATES . .	Semnopithecus entellus (*Dufresne*).
		Cynocephalus, *sp.*
	CARNIVORA . .	Felis tigris (*or* ? leo) *Linn.*
		—— ? pardus, *Linn.*
		—— chaus, *Güldenst.*
		—— rubiginosa, *Geoffr.*
		Hyæna crocuta (*Erxl.*).
		Viverra karnuliensis, *Lyd.*
		Prionodon (?), *sp.*
		Herpestes griseus, *Desm.*
		——— fuscus, *Waterh.*
		——— nipalensis, *Gray.*
		Ursus labiatus, *Blainv.*
	INSECTIVORA . .	Sorex, *sp.*
	CHIROPTERA . .	Taphozous saccolæmus, *Temm.*
		Phyllorhina diadema (*Geoffr.*).
	UNGULATA . .	Equus asinus, *Linn.*
		——— *sp. a.*
		Rhinoceros karnuliensis, *Lyd.*
		Bos *or* Bubalus, *sp.*
		Boselaphus tragocamelus (*Pall.*).
		Genus non. det.
		Gazella bennetti (*Sykes*).
		Antilope cervicapra (*Linn.*).
		Tetraceros quadricornis (*Blainv.*).
		Cervus aristotelis, *Cuv.*
		——— axis, *Erxl.*
		? Cervulus muntjac (*Zimm.*).
		Tragulus (*cf.* meminna [*Erxl.*]).
		Sus cristatus, *Wagner.*
		— karnuliensis, *Lyd.*
	RODENTIA . .	Sciurus macrurus, *Hardw.*
		Gerbillus indicus (*Hardw.*).
		Nesokia bandicoota (*Bech.*).
		——— kok, *Gray.*
		Mus mettada (*Gray.*).
		—— platythrix, *Sykes.*
		—— *sp. var.*
		Golunda ellioti, *Gray.*

[1] The Madras forms are indicated by †.

	RODENTIA—*contd.*	Hystrix crassidens, *Lyd.*
		Atherura karnuliensis, *Lyd.*
		Lepus (*cf.* nigricollis, *F. Cuv.*).
	EDENTATA . .	Manis gigantea, *Illiger.*
AVES . . .	ACCIPITRES . .	Neophron percnopterus (*Linn.*).
		? Milvus *or* Circus, *sp.*
	STRIGES . . .	Ketupa ceylonensis (*Gmelin*).
		Bubo coromandus (*Lath.*).
	GALLINÆ . .	Francolinus pictus (*Jard. and Selby.*).
		——— pondicerianus (*Gmelin*).
	ALECTORIDES . .	Grus (*cf.* communis, *Bechst.*).
	HERODIONES . .	Ibis melanocephala (*Lath.*).
REPTILIA . .	CROCODILIA . .	Crocodilus, *sp.*
	LACERTILIA . .	Varanus dracæna (*Shaw.*).
	OPHIDIA . .	Python molurus (*Linn.*).
		Naia tripudians (*Merr.*).
		Ptyas mucosus (*Linn.*).
AMPHIBIA . .	BATRACHIA . .	Bubo (*cf.* melanostictus, *Schneid.*).

c. The Kistna Valley.

MAMMALIA . .	UNGULATA . .	Rhinoceros deccanensis, *Foote.*
		Bos *or* Bubalus, *sp.*

d. The Narbada, Jamna, Godaveri, and Pemganga Valleys.

" . .	CARNIVORA . .	Ursus namadicus, *F. & C.*
		Felis (? tigris, *or* leo, *Linn.*).
	UNGULATA . .	Elephas namadicus, *F. & C.*
		——— ganesa, *F. & C.*
		? ——— insignis, *F. & C.*
		Rhinoceros unicornis, *Linn.*
		——— namadicus, *F. & C.*
		Equus namadicus, *F. & C.*
		Bubalus buffelus (*Blum.*).
		Bos namadicus, *F. & C.*
		Leptobos fraseri, *Rüt.*
		Boselaphus namadicus (*Rüt*).
		Antilope cervicapra, *Pall.*
		Cervus aristotelis, *Cuv.*
		? ——— duvaucelli, *Cuv.*
		——— porcinus, *Zimm.*
		Sus cristatus, *Wagn.*
		Hippopotamus palæindicus, *F. & C.*
		——— namadicus, *F. & C.*
	RODENTIA . .	Muridæ, *gen. non. det.*
REPTILIA . .	CROCODILIA . .	Crocodilus, (?) *sp.*
	CHELONIA . .	Pangshura flaviventris, *Günth.*
		Batagur (*cf.* dhongoka, *Gray.*).
		Trionyx gangeticus, *Cuv.*

2. PLIOCENE AND (?) UPPER MIOCENE.

a. Hundes Valley in Tibet.

MAMMALIA . .	CARNIVORA . .	Hyæna, *sp.*
	UNGULATA . .	Hipparion, *sp.*
		Pantholops, (?) hundesiensis, *Lyd.*
		Capra, *sp.*
		Ovis, (?) *sp.*

	UNGULATA—*contd.* Artiodactyla.		Dorcatherium majus, *Lyd.*
			——— minus, *Lyd.*
		†	Chœromeryx silistrensis (*Pent*).
		††	Agriochœrus (?) *sp.*
		††	Hemimeryx blanfordi, *Lyd.*
			Merycopotamus dissimilis, *F. & C.*
			——— nanus, *Lyd.*
		‖	——— pusillus, *Lyd.*
		††	Hyopotamus palæindicus, *Lyd.*
		††	——— giganteus, *Lyd.*
		†	Anthracotherium silistrense (*Pent*).
		††	——— hyopotamoides, *Lyd.*
			——— *sp. a.*
			——— *sp. b.*
			Tetraconodon magnus, *Falc.*
		††	Hyotherium sindiense, *Lyd.*
		‡	——— perimense, *Lyd.*
			Hippohyus sivalensis, *F. & C.*
			——— *sp.*
			Sanitherium schlagintweiti, *Myr.*
			Sus giganteus, *F. & C.*
		‖	—— titan, *Lyd.*
			—— falconeri, *Lyd.*
		†	—— hysudricus, *F. & C.*
		‖	—— punjabiensis, *Lyd.*
			—— *sp.*
		‖	Listriodon pentapotamiæ, *Falc.*
		‖	——— theobaldi, *Lyd.*
		*	Hippopotamus iravaticus, *F. & C.*
			——— sivalensis, *F. & C.*
	RODENTIA . .		Nesokia, *sp.*
			Rhizomys sivalensis, *Lyd.*
			Hystrix sivalensis, *Lyd.*
			Lepus, *sp.*
	EDENTATA . .	††	Macrotherium sindiense, *Lyd.*
AVES . . .	STEGANOPODES .		Phalacrocorax (?) *sp.*
			Pelecanus cautleyi, *Dav.*
			——— (?) sivalensis, *Dav.*
	HERODIONES . .		Leptoptilus falconeri (*M. Ed.*).
			Gen. non. det.
	ANSERES . . .	?	Mergus, *sp.*
	STRUTHIONES . .		Struthio asiaticus, *M. Ed.*
REPTILIA . .	CHELONIA . .		Colossochelys atlas, *F. & C.*
			Genus non det, sp. a.
			——— *sp. b.* (? *Cautleya annuliger* Theob.)
			——— *sp. c.*
			——— *sp. d.*
		‖	Clemmys sivalensis (*Theob.*).
		‖	——— hydaspica, *Lyd.*
		‖	——— theobaldi, *Lyd.*
		‖	——— punjabiensis, *Lyd.*
			——— *sp. a.*
		‡	——— watsoni, *Lyd.*
			——— palæindica, *Lyd.*

			Clemmys (?) *sp. b.*
	CHELONIA—*contd.*		Pangshura flaviventris, Günth. (?)
			——— *sp. a.*
			Batagur falconeri, *Lyd.*
			——— bakeri, *Lyd.*
			——— durandi, *Lyd.*
			——— cautleyi, *Lyd.*
			Genus non det. (? Geoemyda) *sp.*
			Emyda vittata, *Pet.*
			——— lineata, *Lyd.*
			——— sivalensis, *Lyd.*
			——— palæindica, *Lyd.*
			Trionyx, *sp.*
			Chitra indica, *Gray.*
	CROCODILIA . .		Crocodilus sivalensis, *Lyd.*
		‡	——— palæindicus, *Falc.*
			Garialis gangeticus (*Gmel.*).
			——— hysudricus, *Lyd.*
		††	——— curvirostris, *Lyd.*
			——— leptodus (*F. & C.*).
		††	——— pachyrhynchus, *Lyd.*
			Rhamphosuchus crassidens (*F. & C.*).
	LACERTILIA . .		Varanus sivalensis, *Falc.*
	OPHIDIA . .	‖	Python molurus, *Linn.*
		‖ †	——— *sp.*
PISCES . .	CHONDROPTERYGII .	‖	Carcharias, *sp.*
		*	Carcharodon, *sp.*
Teleostei.	ACANTHOPTERYGII .		Ophiocephalus, *sp. a.*
			——— *sp. b.*
	PHYSOSTOMI . .		Clarias falconeri, *Lyd.*
			Heterobranchus palæindicus, *Lyd.*
		‖	Chrysichthys (?) theobaldi, *Lyd.*
			Macrones aor, *B. Ham.*
		‖	Rita grandiscutata, *Lyd.*
			Arius, *sp. a.*
		‖ †	——— *sp. b.*
			Bagarius yarrelli (*Syk.*).
			Cyprinodontidæ, gen. non. det.

3. MIOCENE.

MAMMALIA . .	UNGULATA . .		Rhinoceros sivalensis, *var.* gajensis, *Lyd.*

4. EOCENE.

" . .	" . .	(?)	Palæotherium, *sp.*
			Gen. non. det. (*Artiodactyle*).
REPTILIA . .	CHELONIA . .		Platemys leithi (*Carter*).
			Hemichelys warthi, *Lyd.*
			Gen. non. det.
	CROCODILIA . .		*Gen. non. det.*
AMPHIBIA . .	BATRACHIA . .		Oxyglossus pusillus (*Owen*).
			——— (?) *sp.*
PISCES . .	CHONDROPTERYGII .		Myliobatis curvipalatus, *Lyd.*
	ACANTHOPTERYGII .		Capitodus indicus, *Lyd.*
			Cœlorhynchus, *sp.*
	PLECTOGNATHI .		Diodon foleyi, *Lyd.*

II.—MESOZOIC AND PALÆOZOIC.

1.—CRETACEOUS.

REPTILIA . .	DINOSAURIA . .	Megalosaurus, *sp.*
		Titanosaurus blanfordi, *Lyd.*
		——— indicus, *Lyd.*
		Gen. non det.
	CHELONIA . .	*Gen. non det.*
	CROCODILIA . .	*Gen. non det.*
	ICHTHYOSAURIA .	Ichthyosaurus indicus, *Lyd.*
PISCES . . *Palæichthyes.*	CHONDROPTERYGII .	Corax incisus, *Eger.*
		——— pristodontus, *Agas.*
		Lamna complanata, *Eger.*
		——— sigmoides, *Eger.*
		——— (Oxyrhina) triangularis, *Eger.*
		——— *sp.*
		Odontaspis constrictus, *Eger.*
		——— oxypeion, *Eger.*
		Otodus basalis, *Eger.*
		——— divergens, *Eger.*
		——— marginatus, *Eger.*
		——— minutus, *Eger.*
		——— nanus, *Eger.*
		——— semiplicatus, *Eger.*
		Ptychodus latissimus, *Agas.*
	GANOIDEI . .	Pycnodus (?) *sp.*
		Sphærodus rugulosus, *Eger.*
	ACANTHOPTERYGII .	Enchodus serratus, *Eger.*

2.—GONDWANA (*Jura to Permian.*)[1]

REPTILIA . .	DINOSAURIA . .	† Epicampodon indicus (*Hux.*).
		‡ *Gen. non det.*
	CROCODILIA . .	(?) * *Gen. non det.*
		‡ Parasuchus hislopi, *Lyd.*
		‡ Belodon, *sp.*
	ANOMODONTIA .	‡ Hyperodapedon huxleyi, *Lyd.*
		† Dicynodon orientalis, *Hux.*
		† ——— *sp.*
	PLESIOSAURIA . .	* Plesiosaurus indicus, *Lyd.*
AMPHIBIA . .	LABYRINTHODONTIA .	† Gonioglyptus longirostris, *Hux.*
		† ——— huxleyi, *Lyd.*
		† Glyptognathus fragilis, *Lyd.*
		† Pachygonia incurvata, *Hux.*
		‡ ——— *sp.*
		‡ Mastodonsaurus, *sp.*
		‡ *Gen. non det.*
		‖ Brachyops laticeps, *Owen.*
		‖ Gondwanosaurus bijoriensis, *Lyd.*
PISCES . . *Palæichthyes.*	GANOIDEI . .	Ceratodus hislopianus, *Old.*
		——— hunterianus, *Old.*
		——— virapa, *Old.*
		Lepidotus breviceps, *Eger.*
		——— calcaratus, *Eger.*
		——— deccanensis, *Eger.*

[1] The older unfossiliferous beds are probably partly carboniferous. In the table the Maleri and South Rewah forms are indicated by a ‡; those from the Chari and Umia groups by an *; those from the Panchet beds by a †, and those from the Bijori and Mangli by a ‖.

		Lepidotus longiceps, *Eger.*
		——— pachylepis, *Eger.*
		Dapedius egertoni, *Syk.*
		Tetragonolepis analis, *Eger.*
		——— oldhami, *Eger.*
		——— rugosus, *Eger.*
		Gen. non det.

3.—PRODUCTUS-LIMESTONE (*Permian to Carboniferous*).

PISCES . . .	GANOIDEI . .	Sigmodus dubius, *Waag.*
		Saurichthys (?) indicus, *De Kon.*
	CHONDROPTERYGII .	Helodopsis elongata, *Waag.*
		——— abbreviata, *Waag.*
		Psammodus, *sp.*
		Pœcilodus paradoxus, *Waag.*
		Psephodus indicus, *Waag.*
		Acrodus flemingi, *De Kon.*
		——— *sp.*
		Petalorhynchus indicus, *Waag.*
		Xystracanthus gracilis, *Waag.*
		——— major, *Waag.*
		——— giganteus, *Waag.*
		Thaumatacanthus blanfordi, *Waag.*

APPENDIX.

Mastodonsaurus *from N. S. Wales.*—In 'Nature' of December 16th, 1886, is published a note recording the reported occurrence in the Haukesbury group of the Gondwánas of New South Wales of a ***Mastodonsaurus*** apparently allied to ***M. giganteus*** of the European Muschelkalk and Keuper. This determination (which was made by comparison with a cast of the Stuttgart skull, and is therefore probably correct) is of great interest in respect to the occurrence of an allied member of the genus in the Denwa group.[1]

The recent observations of Mr. Oldham[2] indicate that the Haukesbury beds are probably separated by an unconformity from the underlying Newcastle group, and that the latter is nearly related in time with the Damuda series (Ranigunj, Bijori, and Barakar groups). The presence in both the Denwa and Haukesbury groups of an allied (or perhaps identical) species of ***Mastodonsaurus***, the restricted vertical distribution of that genus in Europe being borne in mind, suggests very strongly the approximate equivalence of these groups. The Denwa group belongs to a considerably higher horizon than the Damuda series[3] (Newcastle group), and the elevation of the Haukesbury beds to the same approximate level would accord with the unconformity between the latter and the Newcastle group.

With regard to the homotaxy of the Indo-Australian Gondwánas with the European succession, it may be observed that the Australian sequence rests on marine beds correlated by Dr. Waagen[4] with the lower carboniferous, and that the three groups[5] below the Newcastle consequently correspond to the upper carboniferous; in which division, according to Mr. Oldham's identifications, may likewise be included the Indian Talchirs and the Victorian Bacchus Marsh beds.[6] This being so, the Newcastle and Damudas might correspond to the permian; the Panchets (which might roughly represent the interval between the Newcastle[7] and Haukesbury) to the lower trias; and the Indian Denwa and Maleri and the Australian Haukesbury and Wianamatta to the middle and upper divisions of the latter.

How closely such an homotaxial sequence corresponds with the European horizons indicated by the Gondwána vertebrates of India has been already noticed by myself;[8] and this correspondence is strengthened by the evidence of the Haukesbury ***Mastodonsaurus***. It is true that a certain discrepancy is introduced by the occurrence in the latter beds of ***Palæoniscus*** and ***Myriolepis***, but since one species of the former is found in the European upper trias, there is no reason, especially when we recall the persistence in Australia of ***Ceratodus***, why the latter genus should not also have survived in that country to the same epoch.

[1] *Supra*, p. 68.

[2] *Supra*, Vol. XIX. p p. 40, 46.

[3] See table on p. 108 of the 'Manual of the Geology of India.'

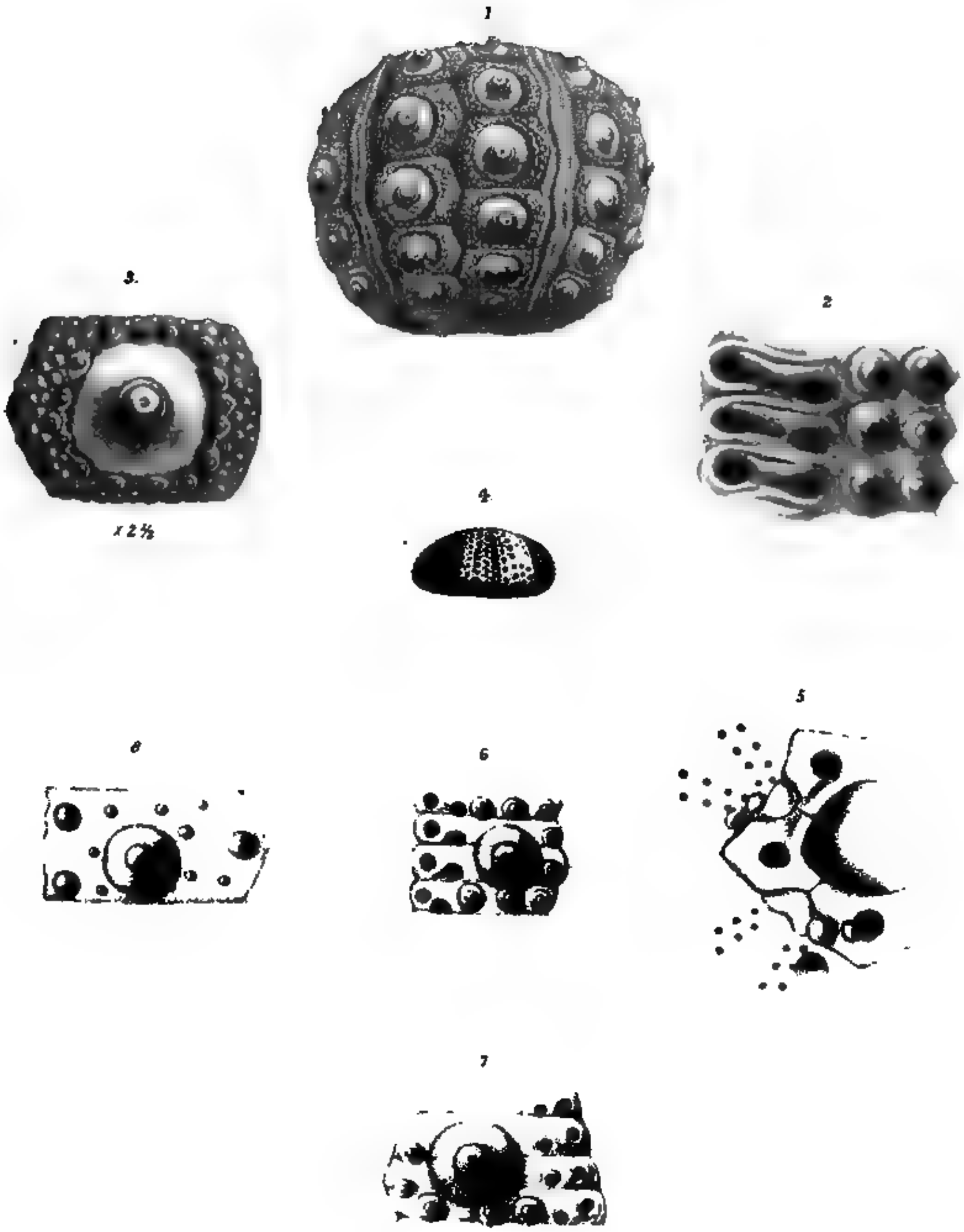
[4] *Supra*, Vol. XIX. p. 35.

[5] *Ibid.* p. 40, note.

[6] *Ibid.* p. 43.

[7] Dr. Waagen in the passage cited followed Dr. Feistmantel's erroneous view of correlating the Bacchus-Marsh with the Haukesbury beds, and of removing the Newcastle from the Damudas, which are regarded as probably permian.

[8] *Ibid.* p. 133.



A. S. Foord del. et lith.

Cretaceous Echinoidea from Bág.

Mintern Bros. imp.

Note on the Echinoidea *of the* Cretaceous *series of the* Lower Narbadá Valley, *with remarks upon their Geological age, by* PROFESSOR P. MARTIN DUNCAN, F.R.S., &C., *November 1886.*

CONTENTS.—History of the geological and palæontological researches amongst the Cretaceous rocks of the Bág district — A criticism of the palæontology and geological results given in "The Geology of the Lower Narbada Valley, by P. N. Bose, B.Sc., Lond., F.G. S.," in Memoirs of the Geological Survey of India — Lists of the Echinoidea — Deductions — Description of New Species and notices of the forms already known — Description of Plate.

In 1865 my attention was directed to a small collection of Echinodermata, Mollusca, and other fossils in the Museum of the Geological Society of London, which had been presented by Dr. H. Carter, F.R.S. The specimens came from strata near Bág in the Lower Narbadá Valley, and they were collected by Captain Keatinge.

The existence of at least eight European types in the small collection, impressed me very much, as did also their unmistakable Upper Greensand facies. A correspondence with Dr. Carter led to the examination of the fossils from S. E. Arabia, which had been collected by him from strata which he considered to be of the same age as the Indian beds and which presented the same mineralogical characters. The specimens from S. E. Arabia were more numerous than those of the Bág beds, and out of eight species of Echinodermata, seven were recognized as European Upper Greensand forms. The Mollusca, a Brachiopod and a Coral from Bág told the same story of the persistence, with slight variation, into the East, of species such as *Salenia scutigera*, *Pygaster truncatus*, *Epiaster distinctus*, &c., *Pecten quadricostatus*, *Neithia alpina*, *Rhynchonella depressa* and *Thamnastræa decipiens*. The commonest fossils were referable to *Hemiaster Cenomanensis*, Cott., and *Hemiaster similis*, d'Orb. A communication was published in the Quar. Jour. Geol. Soc., 1865, Vol. XXI, page 348, dealing with the collections and asserting the Upper Greensand age of the somewhat widely separated groups of strata.

In 1866 Messrs. Blanford and Wynne made as satisfactory a survey of the Lower Valley of the Narbadá as was possible, without the aid of a perfect geographical map. (Mem. Geol. Sur. Ind. VI, pages (207)—(219), (294)—(302), also Blanford, Geol. Bombay, Rec. Geol. Sur. Ind. Vol. V, pt. 3, p. 82. 1872.)

The Surveyors stated that the Cretaceous strata which had been called the Bág beds, rested in one place unconformably on an outlier of the Upper Gondwána series, and that there was a succession, from below upwards, of sandstone and conglomerate, 20 feet, Nodular limestone, nearly unfossiliferous, 20 feet, Argillaceous limestones, fossiliferous, 10 feet, and Coralline limestone (Bryozoan), 10 to 20 feet.

The beds were described and their relation to the overlying Deccan trap explained; moreover it was discovered that the fossils which had come under my notice had been obtained from the Argillaceous limestone. Blanford accepted the particular geological horizon which I considered the species indicated.

In 1868, the Upper Greensand horizon was recognized from the fossils, which were collected by Mr. Holland and subsequently by Mr. Bauerman, in the area of Sinai (Quar. Jour. Geol. Soc., Vol. 23, read December 1866, page 38 (not noticed in the list of contents) and Quar. Jour. Geol. Soc., Vol. 25, page 44, read December 9, 1868, published in 1869).

Two of the species of Echinoidea which had been noticed at Bág and in S. E. Arabia besides many well known Upper Greensand forms were found in one of the collections from Sinai, and in the second collection no less than 13 out of 24 species were recognized as being members of the strata above the Gault and below the horizon of the White Chalk in N. Africa (Algeria). Eight species were found to be common to the Sinai range and Tih and the Upper Greensands of Europe.

In 1873, the late Ferd. Stoliczka had his great work on the Echinodermata of the Cretaceous rocks of S. India published in the Palæontologia Indica, and it became evident that this interesting series of strata did not contain the commonest species of the Echinoidea of Bág and the Arabian districts. Yet an Upper Greensand horizon was clearly identified in S. India, from the facies of the Corals and some of the mollusca, moreover there were European Cenomanian species present. The remarkable fauna of the three groups of Cretaceous strata in S. India had been the source of much consideration amongst European palæontologists, and there were hopes expressed that a further search for fossils would be made amongst the Cretaceous rocks of the Narbadá Valley, so as to obtain the requisite data for a better comparison of the distant strata.

Stoliczka considered that the strata in S. India represented the European Cenomanian, Turonian and Senonian, to the top of the White Chalk. The Ammonites of the lower divisions gave a Gault facies, but Stoliczka noticed that the species which gave the facies had a great vertical distribution in Europe and were found in both Gault and Cenomanian.

In 1880, Mr. P. N. Bose, B.Sc., Lond., F.G.S., of the Indian Geological Survey, was ordered to proceed to the Lower Narbadá Valley and to pay during his survey special attention to the fossiliferous strata and igneous rocks. Mr. Bose had the advantage of an excellent geographical map, and the results of his survey were published in the Memoirs of the Geological Survey of India, Vol. xxi, pt. I. 1884.

Mr. Bose writes with great modesty, not unflavoured with some critical sharpness, when dealing with his predecessors in the stratigraphical part of his work, and he also most straightforwardly asserts his shortcomings as a palæontologist. He states that his determinations of species were "roughly done," and that he availed himself of the assistance of the most careful palæobotanist Herr Feistmantel.

The lists of species published by Mr. Bose are those of the specimens which he collected; he did not avail himself of the collection made, years before, by Keatinge and which is in the Museum at Calcutta, nor did he include the species which had been described by me in the communication already noticed. But in the lists it will be noticed that Mr. Bose places certain forms "taken on the authority of Dr. Duncan's identification." This is hardly correct, for I did not see Mr. Bose's collection, neither did I identify any species for him. I identified the species he names in the collection of the Geological Society, but that is quite another matter.

The succession of strata belonging to the Cretaceous formation in the Lower Narbadá area is according to Mr. Bose, at the bottom—

1. A sandstone, "The Nimar," conglomeratic at the base and fine-grained at the top except where in places an oyster bed is found.

2. Nodular-limestone.

3. The calcareous marl, of Deola and Chirákhán.
4. Coralline-limestone (Bryozoan).
5. Lametas (fresh-water).

He confirms Blanford and Wynne's survey in reference to the conformity of the whole of the marine beds, and states, as they did, that the Laméta freshwater beds rest on the eroded surfaces of the underlying Cretaceous strata, and that the Deccan and Malwa Trap covers the Lametas and the eroded Cretaceous strata.

Mr. Bose found an Oyster bed on the top of the sandstone (page 33), and states that it was about a foot in thickness; it rests quite conformably upon some horizontal, extremely coarse grit stones of insignificant thickness and passes above, equally without break, into the lowest beds of the Upper Cretaceous limestone series (nodular limestone). "The species is near, so far as I can make out, to *Ostræa Leymerii*, an European Neocomian form." Now it is evident that this doubtful Ostræa is not restricted to the lower strata, for (page 33) it is stated :—"At Ghátiá the oyster bed passes under flesh coloured limestones with Bryozoa and bivalves elsewhere met with in the nodular limestone, as well as with diminutive forms of the Ostræa just described [? mentioned] in much diminished numbers."

Mr. Bose proceeds (page 34):—"It may seem ridiculous to attempt to fix the age of a deposit, with any approach to precision, on the approximate identification of only one fossil and that, too, merely an oyster. But this bivalve is a very characteristic fossil of the deposits under consideration, and if it passes up to the overlying limestone, it does so in considerably diminished numbers, and as a rule in diminutive forms and dies out in the course of deposition." On page 34 it is further stated—"Now the nodular limestone, which contains a well defined marine fauna, will be shown in the next chapter to be on the horizon of the Gault or Albian of the European Cretaceous system. We may, therefore, ascribe the oyster-bearing beds, not without some show of probability, to a lower (neocomian) horizon. The oyster being closely allied to an European neocomian form adds strength to the supposition."

These extracts require no comment from a palæontologist except the suggestion that it is a pity that Mr. Bose did not understand the meaning of "a characteristic species," and that he did lean upon such an infirm support as an Oyster of doubtful identity. Unfortunately Mr. Bose states further on in his memoir that the age of the underlying sandstone is unsettled.

The Nodular-limestone is stated to be of Gault age and the list of species is given (page 37). No fossils of this zone had been examined by any one before Mr. Bose made his interesting collection. The fossils of the Deola and Chirákhán marl, which rests conformably upon the Nodular-limestone, which also is often, according to Mr. Bose, marly in its nature, are numerous, and there are 29 forms which Mr. Bose has distinguished generically and in some instances specifically. He assigns the horizon of the fauna to the Cenomanian "or" to use his expression "at about the same horizon," the Turonian being included.

The Coralline-limestone is said to rest conformably on the Marl, and Mr. Bose notices six forms, two of which he names generically, Ostræa and Rhynchonella, and the others he gives specific names to. This limestone is placed by Mr. Bose on the horizon of the Senonian, and as he compares it with the Arriálur series of S. India, it must be placed high up in the Upper Cretaceous series.

In a recapitulation and statement of general results (page 48), Mr. Bose tabulates his succession of deposits, and modifies his former statements slightly. The Nodular limestone is now placed in an Albian and partly Cenomanian series; the Marl is partly Cenomanian and partly Turonian and the Coralline is Senonian. He places the Lametas with the Corallines in the Senonian.

It will be observed that Mr. Bose considers that the Neocomian is present at the bottom of a conformable limestone series, which has about 80 feet of vertical measurement at the greatest, and probably much less, and which may be sub-divided into Albian, Cenomanian, and Senonian and that all the S. Indian Cretaceous strata are represented in Narbadá area.

It is also evident that Mr. Bose agrees in the main with me about the age of the Deola and Chiríkhán Marl. One of his remarks, however, requires notice. It is stated (page 48)—"These conclusions would appear to be at variance with that suggested by Keatinge, worked out by Duncan and accepted by Blanford, *viz.*, that the Bág rocks (in the widest and hitherto accepted sense of the expression) are assignable to about the same horizon as the Upper Greensand, and must in consequence, as remarks Mr. Blanford, closely correspond to the Utátur group of S. India. But considering that the data upon which this inference was based were still more insufficient than those collated in this report, it in reality rather tends to corroborate than otherwise the homotaxy indicated here." The last part of the paragraph is incomprehensible, and it was with some regret that I read Mr. Bose's acknowledgment of the insufficiency of the palæontological data upon which he based his stratigraphical succession of the whole Cretaceous formation in the N. W. of the Peninsula.

It is clear that the fossils named by myself came from one part of the Cretaceous series, and it will be found that I did not include any other strata in the Upper Greensand horizon except those which yielded the forms which in my opinion were sufficient to stamp the horizon. I referred to the necessity for Captain Keatinge being held responsible for the stratigraphical position of the fossils I named, and as I found *Hemiaster Cenomanensis*, Cott., *H. similis*, d'Orb., *Nucleolites similis*, Desor, and *Echinobrissus subquadratus*, d'Orb., sp., besides *Neithea alpina*, d'Orb., *Pecten quadricostatus*, Sow., *Rhynchonella depressa*, Sow., and *Thomnastræa decipiens*, Mich. sp., all species, except one, found only in the Cretaceous series of Europe between the Gault and the Chalk within Flints in Europe I had no hesitation in generalizing. The general Upper Greensand age was, therefore, determined with the aid of sufficient data, and it referred to the strata out of which the fossils came and to no others as Mr. Bose would infer. I had no fossils from the Nodular-limestone nor from the Coralline beds.

Having studied Mr. Bose's memoir, and having failed to agree with his deductions, from the species which he had named, regarding the ages of the Bág series, I applied to the Director of the Geological Survey of India, H. B. Medlicott, Esq., F.R.S., for the loan of all the Echinoidea which he could get me from the Bág district, including Mr. Bose's collection and named specimens. My request was granted, and I have received the fossils and in addition a collection made by Mr. Blanford and the original specimens which were collected so many years since by Captain Keatinge from the Marl.

The following is a list of the species which I have determined and the particular group of strata from which each was derived :—

NAME.	GROUP OF STRATA.	FOREIGN SERIES.
1. *Cidaris Namadicus*, sp. nov.	Deola and Chirákhán Marl and Corallines.	......
2. *Salenia Fraasi*, Cott.	Deola and Chirákhán Marl	Lebanon, Cenomanian.
3. *Cyphosoma Cenomanensis*, Cott.	Deola and Chirákhán Marl and Corallines.	Europe Cenomanian.
4. *Othopsis Indicus*, sp. nov.	Deola and Chirákhán Marl	......
5. *Echinobrissus Goybeti*, Cott.	Deola and Chirákhán Marl	Lebanon, Cenomanian.
6. *Nucleolites similis*, var. d'Orb.	Deola and Chirákhán Marl, Corallines.	Chloritic Marl, Europe.
7. *Hemiaster Cenomanensis*, Cott.	Nodular limestone, Deola and Chirákhán Marl, Corallines.	Europe, Cenomanian.
8. *Hemiaster similis*, d'Orb.	Nodular limestone, Deola and Chirákhán Marl, and Corallines.	Europe, Cenomanian.

The two species of Hemiaster are the commonest fossils, and any number of them may be examined from *each of the three* divisions of the Bág beds. They are Cenomanian forms in Europe. This persistence of common species throughout the three groups of beds, to each of which Mr. Bose has given a different horizon, renders the possibility of there being an Albian, a Cenomanian, and a Senonian at Bág very doubtful, and the following table of the distribution of the Echinoidea in the strata of the Bág area will add to the impossibility of crediting the presence of the whole Middle and Upper Cretaceous series in the same locality :—

NAME.	NOD.-LIMESTONE.	MARL.	CORALLINE.
Cidaris Namadicus, sp. nov.	o	...	...
Salenia Fraasi, Cott.	o	...	o
Cyphosoma Cenomanense, Cott.	o	...	...
Orthopsis Indicus, sp. nov.	o	...	o
Echinobrissus Goybeti, Cott.	o	...	o
Nucleolites similis, d'Orb. var.	o	...	...
Hemiaster Cenomanensis, Cott.	...	...	...
Hemiaster similis, d'Orb.	...	...	...

There are no Albian forms in this list, nor are there any Senonian species, and it is perfectly evident from the evidence afforded by the Echinoidea, that the strata which yielded specimens to Captain Keatinge, and which were described in 1865, must be considered to be on the European Cenomanian horizon and on that which stretches through S. E. Arabia, Sinai, the Lebanon, and Algeria into Europe.

The study of the Echinoidea contradicts Mr. Bose's statements.

It will be noticed that in the lists of species three of those included in Mr. Bose's lists are wanting. Having examined the specimen which he attributed to *Cidaris Cenomanensis*, Cott., I find specific differences and a very remarkable one in the ornamentation of the test beyond the scrobicules of the primary tubercles, moreover the scrobicular margins are also not those of the European form. I consider, however, that Mr. Bose was justified in giving the name he did as he states "roughly," for the general shape and the nature of the ambulacra would lead anybody to place the species near to the French form. The species of Orthopsis was considered by

Mr. Bose to be the same as that described by Stoliczka from the Arriálur deposits of Southern India; but there are specific distinctions, and a new species has to be diagnosed. The third species is *Echinobrissus sub-quadratus*. Thanks to M. Cotteau, a species has been described in which there are the remarkable petaloid ambulacra which made me hesitate years since in placing the Bág form in the Neocomian *E. sub-quadratus*.

On carefully re-studying the collection of the Echinoidea given by Dr. Carter to the Geological Society and which was described in 1865, I find it only necessary to replace *Echinobrissus sub-quadratus* by *Echinobrissus Goybeti*, Cott. There is no reason for interfering with the determinations made of the mollusca, brachiopod, and coral; they are all Upper Greensand forms, but it must be understood that they came from the Deola and Chirákhán Marl.

In conclusion it is absolutely necessary to remark upon the palæontological proofs offered by Mr. Bose that the Coralline limestone and the Nodular limestone, the upper and lower beds in a conformable series, are on the Senonian and Albian horizons respectively.

The following are forms from the Coralline according to Mr. Bose, *Ostræa* sp., *Rhynchonella plicatiloïdes*, Stol., *Rhynchonella* sp., *Ceriopora dispar*, *Hemiaster similis*, and *H. Cenomanensis*. Mr. Bose remarks as follows (pp. 43-44):

"This number is perhaps too small to reason upon. But the disappearance of all the most characteristic forms of the underlying beds has to be noted; and the special prominence and abundance of forms which had occupied a very subordinate position in the fauna of the latter, indicate considerable changes of physical conditions, and consequently a proportionate lapse of time. The remarkable change in the mineral character also proves a corresponding alteration in the configuration of the cretaceous seas and therefore in the physical geography of the country from which the rivers derived their sediment. On these considerations, and on the strength of the fact that two of the most characteristic forms occur in the Arriálur division of the South Indian cretaceous series, I am inclined to correlate the Coralline limestone, of course roughly, with the latter."

Divested of useless matter the palæontology of the Coralline so far as it is known to Mr. Bose relates to four species, three of which are common in the underlying Deola and Chirákhán Marl, and the fourth, less commonly found, is the *Rhynchonella plicatiloides*, Stol. Two of the species occur also in the Nodular limestone. So there is no special abundance of forms which had occupied a subordinate position, and indeed the two Hemiasters are *the most prominent* of the species of the underlying strata !!! Which are the two characteristic forms of the Coralline limestone it is impossible to state, for none of the species given by Mr. Bose are characteristic of the beds, the whole of the named species being found in underlying strata. He states however that the two occur in the Arriálur strata of Southern India, so by a process of elimination it may be possible to understand which species are meant. The two Hemiasters are not found in Southern India and that leaves *Rhynchonella plicatiloïdes*, Stol., and *Ceriopora dispar*, Stol. Now the first mentioned is more common in the South Indian series *which underlies the Arriálur beds*, than in the Arriálurs themselves; so the form is not characteristic of the Arriálur. The Bryozoon is found in the Arriálur beds of Southern India and in no others there; but it is

not characteristic of the Coralline limestone, for it is in Mr. Bose's list of both of the underlying strata, and in fact it passes up from the Nodular limestone through the Marl into the Coralline limestone. After these considerations Mr. Bose's correlation must be regarded as too rough to be true. No sufficient evidence has been offered which will place the Coralline limestone on the Arriálur horizon.

With regard to the palæontology of the Nodular limestone, the supposed Albian: it is stated (Bose *op. cit.* p. 39) that the majority of the characteristic forms occur on the horizon of the "Étage Albien (Gault)" and "that therefore there need be little hesitation in considering the Nodular limestone homotaxial with it, as well as with the lowest group of the South Indian Cretaceous series, the Utáturs."

Firstly, the Utátur strata, so splendidly considered palæontologically by Stoliczka, are not of the Albian or Gault age.

Secondly, on studying Mr. Bose's list of species it appears that the solitary Ammonite is elsewhere found in a higher cretaceous horizon than the Gault; and that the three Gasteropoda specifically determined, all belong to higher horizons than the Utátur in Southern India. The Bryozoon is said to be the same which is found in the *highest* and not in the *lowest* of the Southern Indian series. The two Hemiasters are Cenomanian in Europe and are found throughout the Bág beds. The Lamellibranchiata are, according to Mr. Bose's rough determination, very remarkable. The Neocomian Ostræa *O. Leymerii*, is there, with *Inoceramus concentricus*, of whose Upper Greensand as well as Gault horizon Mr. Bose was not acquainted. *Cardium altum*, Forbes, is an Utátur shell, but it occurs in the Marl above the Nodular limestone also. *Inoceramus Coquandianus*, d'Orb., is the only Gault form. Three other species which will require more than simple rough determination before their presence is credited are said to be Neocomian.

All the reliable evidence is in favour of the Nodular limestone being above the Gault and belonging to the Upper Greensand horizon.

Conclusions.—The same species of Echinoidea are common in the three divisions of the Cretaceous series in the Lower Narbadá Valley, the sandstone being admitted by Mr. Bose to be of doubtful age is not included in this statement. The species thus persistent and four others which have a more limited vertical distribution are found in strata above the Gault and below the Senonian in Palestine and Europe. The three divisions of the Cretaceous series are conformable in their stratification. According to the elementary laws of Geology, strata which have species in common and are conformable were deposited during the continuance of one aspect of nature and belong therefore to a geological age, and not to more than one.

The Nodular and Marly and Coralline limestones are, therefore, deposits which accumulated during the Cenomanian age, that term being in a general sense the same as the Upper Greensand.

Description of and remarks on the Species.

1. Cidaris Namadicus, sp. nov. Figs. 1-3.

The test is large, high, with the equatorial diameter greater than the polar. Ambulacra narrow, wavy, with deep and wide poriferous zones and a projecting, flat-topped interporiferous area furnished with four close vertical rows of distinct

flattish granules. Pores, elliptical separated by a slight ridge and therefore non-conjugate, pairs numerous, close, separated by a narrow costa with a delicate linear ridge as the ornament. Twenty-five pairs of pores opposite the scrobicule of the largest interradial primary tubercle. Interradia wide, with a well marked median area, becoming deep at the junction of the median and lateral sutures; eight or nine primary tubercles in vertical series in each. Primaries with projecting but somewhat depressed perforated mamelons, rather tall, sloping, wide bosses, without crenulation, sunken externally, either circular in outline or slightly elliptical; scrobicular margin as a raised ring of large secondaries rather wide apart and having a broad flat base on which is placed an irregularly shaped boss with a small mamelon; smaller secondary tubercles or very large granules, placed between the larger secondaries and slightly external to them. Scrobicular rings (abactinally) separate, with some slope beyond them, but close together or running one into the other nearer the ambitus and actinally; scrobicules always distinct. Slope beyond the scrobicules covered with large, irregularly placed, warty granules, rather flat, close, varying in size and with a few small ones near the sutural lines. The scrobicular rings come close to the poriferous zones, without any granular area.

Height, 45 mm.	Equatorial diameter, 50 mm.
" 42 "	" 60 "
" 35 "	" 40 "
" 30 "	" 38 "

Distribution.—Coralline Limestone Bowárla, Kherwan.
" " Chirákhán.
Argillaceous limestone, Chirákhán.

Description of the figures.—1. Part of a test, natural size.
2. Part of an ambulacrum, magnified.
3. A coronal plate with the primary tubercle, magnified.

This is a very fine species and may be known, at once, by the size of the high test, the wavy ambulacra with four rows of granules, the ridge-like linear ornament of the costæ, the close and huge scrobicular rings, the deeply seated median sutures and the large coarse irregular granulation of the slopes. It is unlike any European cretaceous form, but has some affinities with *Cidaris Cenomanensis*, Cott., but this has fewer primaries, wider slopes beyond the scrobicules and a delicate granulation.

2. Orthopsis indicus sp. nov. Figs. 4—8.

Test small, depressed, broader than high, flattish actinally, tumid at the ambitus, slightly convex abactinally. Ambitus circular. Apical system with five unequal, largely perforated basals which extend beyond the radials. Periproctal edge slightly raised. Radial plates small, narrow and unequal, and two or three enter the periproctal ring but no more. Periproct slightly and unequally ovoid, with its greatest diameter obliquely from radial plate II to basal 4. A few large granules are on the basals. Ambulacra narrow, breadth to that of interradia, 1 : 2·5. Pairs of pores in straight, simple series, numerous, close, often oblique; pores large, peripodia low with a median knob-like ridge. Plates primaries alone, near the apex; low and broad compound plates near the ambitus, composed of three low primaries united by straight sutures. (Fig. 6*a*.)

Nearer the apex a low simple primary, carrying from one to three granules, separates the primary tubercle-bearing compound plates, which are composed there of two united primaries (Fig. 6*b*.). Primary tubercles of the ambulacra very small, numerous, perforate, increasing in size from the apex to the peristome, in two vertical rows, placed close to the pairs of pores. Granules few and mostly between consecutive primaries. Small secondary tubercles near the ambitus in the median area.

Interradia broad, with rather high coronal plates; with two principal vertical rows of primary tubercles, less numerous than in the ambulacra, larger than those of the ambulacra but otherwise similar, these extend from peristome to apex and are close to the middle of the plates near the ambitus. Near the apex the rows approach the poriferous zones. A second row of smaller primaries is on the ambulacral side of the rows just mentioned and the tubercles are close to the poriferous zones; these two rows, in each interradium, do not reach much above the ambitus. Two other vertical rows of primary tubercles are close to the median suture and they are as large as the others and reach to the ambitus. Thus there are four vertical rows of primaries and two reach the apex in each interradium. A few large granules are upon the plates and are distant.

Height, 10 mm., breadth 19 mm. Distribution:—Argillaceous limestone.

Figure 4, the test, natural size.
 ,, 5, part of the apical system, magnified.
 ,, 6, part of an ambulacrum, magnified.
 ,, 7, coronal plate near the ambitus, magnified.
 ,, 8, a coronal plate near the apex, magnified.

There is only one specimen of this interesting species in the collection, and the two other forms which were associated with it belong to the species next to be noticed.

Stoliczka described and figured *Orthopsis similis*, Stol., from the Arriálur group of the Cretaceous of Southern India (Pal. Ind., Cret. Faun. S. India, Vol. IV. page 116, pl. VII. 1873), and the new species is closely allied. The differences in the construction of the ambulacra can be appreciated by examining Stoliczka's fig. 2 *d* and that which refers to the ambulacra of the new species (our fig. 6). There is not that difference in the size of the tubercles of the rows of the interradia which is seen in *O. similis*, to be observed in *O. Indicus*, and the median rows extend much nearer the apex in *O. similis* than in *O. Indicus*.

The whole of the radial plates do not enter the periproctal ring in *O. Indicus*, although they all do so in *O. similis*. The shape of the tests differs, and apparently the relative number of coronal interradial and ambulacral plates is not the same in the two forms. Finally the ornamentation of the Bág species is much more delicate than that of the other form. The most important distinctions relate to the radial plates and the construction of the ambulacral plates.

3. Cyphosoma Cenomanense, Cott., 1859: Ech. de la Sarthe, p. 150, pl. XXVI, figs. 13-16.

There are several specimens of this Echinoderm and most of them were collected by Captain Keatinge and are on tablets in the Calcutta Museum, but Mr. Blanford and Mr. Bose collected some others.

Distribution.—Coralline limestone, Bowárla, Kherwan, and S. of Raherda. Mr. Blanford collected near Dussai 15 miles W. of Mandoo. Captain Keatinge's specimens came from the Argillaceous limestone.

The resemblance of the specimens from the Bág series to the type, which has been illustrated by Cotteau with his usual care, is in some instances exact and in the others there is slight and unimportant variation. The numerous vertical rows of primary tubercles at and below the ambitus, six in each interradium, and the bare median space abactinally, with slight sutural markings, readily distinguish the species. In one specimen the construction of the ambulacral plates can be seen, and in the compound plates forming the greater part of the areas there are either four or five components which are arranged in the manner usual to Cyphosoma. (Duncan, Quar. Jour. Geol. Soc., 1885, page 449, fig. 23.) The aboral component is a large primary with the adoral suture curved with the convexity adorally directed. The next plate is a demi, and is shut out from the rest of the geometrically formed compound plate beyond the primary tubercle towards the median suture. The third plate is also a demi-plate; but the fourth is a low plate near the peripodium and expands towards the median line, the greater part of the tubercle being upon it and a considerable portion of the median suture being comprised in it. The next or lowest plate is a primary with the aboral suture convex aborally, or the reverse of what is seen in the upper primary plate.

4. Salenia Fraasi, Cotteau, 1885: Ech. nouv. ou peu connus, ser. 2, fas. 4 (Bull. Soc. Zool. de France) p. 59. Pl. VIII, figs. 1-5.

Syn. *Salenia petalifera*, Fraas (non Agassiz): Aus dem Orient: Geol. Beobacht. am Lebanon, 1878, p. 31.

There are three specimens of this interesting species in the collection made by Captain Keatinge, in the Indian Museum at Calcutta, and it is certainly somewhat remarkable that they should have escaped Mr. Bose's notice in dealing with the palæontology of the region which he surveyed. One of the specimens is so well preserved that the specific characters can be determined readily. The narrow ambulacra with the two close vertical rows of primaries, and the arrangement of the interradial primaries, and secondaries, assimilate the form with *Salenia scutigera*, Agassiz; and the nature of the ornamentation of the apical system places it within Cotteau's Lebanon species which he very properly states is closely allied to *S. scutigera*. *Salenia scutigera* is found on the same horizon as *Salenia Fraasi* in the Lebanon. The locality of *Salenia Fraasi* is in the Argillaceous limestone Chirákhán.

Salenia Arcotensis, Stol., is unfortunately a young specimen and yet the alliance to *Salenia Fraasi* is evident, for both have the close vertical rows of primaries in the ambulacra; but the species are distinct.

5 Echinobrissus Goybeti, Cotteau, 1885, *op. cit.*, page 60, Pl. VIII, figs. 6-10.

A large form of this well marked Echinobrissus is in the Chirákhán Marl and the details of the ambulacra enable it to be associated with the species described from the Lebanon Cenomanian by Cotteau. The very distinctly petaloid nature of

the anterior margin decidedly and the slightly flexuous antero-lateral ambulacra. The fasciole is broad and resembles that of the type.

Hemiaster Cenomanensis, Cott., has been found in the Coralline limestone, Bowárla, Kherwan, and other localities; in the Marl at Chirákhán and in the Nodular white limestone at south of Raherda, on the Uri, and Jogardi, 6 miles southwest of Bág. Mr. Blanford collected numbers from near Dussai, 15 miles west of Mandoo and in the Coralline limestone, Chirákhán.

8. Hemiaster similis, d'Orb, 1854. Pal. Franc., terr. cret., t. VI, p. 229, and Cotteau et Triger Ech. de la Sarthe, p. 212, pl. XXXV.

This species was noticed as a variety, in the collection of the Geological Society in 1865, and a great number of specimens have been collected since from each of the three sets of beds belonging to the Cretaceous of the Lower Narbadá Valley. There is no doubt that there is much variation amongst the specimens, and indeed I wás disposed at first to separate one or two in a closely allied species; but on placing the specimens together in series, it was found that these particular forms were linked on to others, and that the really important specific characters of *Hemiaster similis* are found throughout. There is no doubt that the tendency of the variation is towards *Hemiaster nucleus*, Desor, 1847, of the Turonian. The plump shape of the test, the shallow anterior groove not notching the anterior margin, the short postero-lateral ambulacra and the close broad fasciole are present in the forms, and those are the important characters of the species. It is interesting to find more specimens of this Upper Cenomanian species in the Nodular limestone than of the other Hemiaster.

DESCRIPTION OF THE PLATE.

Fig. 1. Cidaris namadicus, sp. nov., natural size.
" 2. " " part of an ambulacrum magnified.
" 3. " " A coronal plate with a primary tubercle magnified.
" 4. Orthopsis indicus, sp. nov., natural size.
" 5. " " part of the apical system.
" 6. " " part of an ambulacrum, magnified.
" 7. " " A coronal plate near the ambitus, magnified.
" 8. " " A coronal plate near the apex, magnified.

Field-notes: No. 5—*to accompany a* Geological Sketch Map *of* Afghanistán *and* North-Eastern Khorassan, *by* C. L. GRIESBACH, C.I.E., *Geological Survey of India.*

Physical characters.

Afghanistán is a land of high mountain ranges and two great areas of steppes; about three-fourths of its drainage passes to the Indus and to the inland basin of the Helmund, and only the northern portion, not much more than one-fourth of the entire area, belongs to the Aralo-Caspian depression.

Ranges.

By far the most important of all the ranges of Afghanistán are the Hindu Kúsh and Koh-i-Bába chains of mountains, which connectedly form the watershed of Afghanistán. The Hindu Kúsh has a north-east to south-west direction, and divides the drainage of the Oxus river from that of Chitral, Kafiristán, and Kabul; the range joins the Koh-i-Bába near the Shibar pass south-east of Bamián, and thence pursues a more or less east and west direction. The western prolongation of this chain forms the watershed between the Seistán drainage and the Hari Rúd (Tejénd) and is known under various local names. In Khorassan the same system of ranges continues, but has a north-west strike.

The range or system of ranges which comes next in importance after the great Central Afghan watershed is the system of parallel ranges which forms more or less the political boundary between India and Afghanistán, namely, the chains amongst which the central portion is known on our maps as the Sulimán range, named after the highest point in the range—the Takht-i-Sulimán. Geographically all the parallel ranges, from the Afridi hills near Peshawar to the Búgti hills south-west of Dera Ghazi Khán, form one connected system of mountains.

The entire intervening area between the Sulimán mountains and the great Afghan watershed is formed by a series of high chains with wide troughs between. They start in the Kabul district and gradually diverge as they are followed south-westwards to the Persian frontier.

The structure and origin of these ranges is very simple. They are formed by a series of anticlinals, often compressed into a narrow belt with steep folds, at other points forming wide arches, and in some cases even plateaux.

Rivers.

The drainage of Afghanistán belongs to three separate areas. The Indus basin receives the drainage which flows from the Hindu Kúsh, Kafiristán, the Sulimán range, and of the ground west of it. The streams which rise in the Búgti hills and part of Biluchistán also run into the Indus basin.

The Ghilzai country and the southern Hazarajat send forth streams, which drain into the inland basin of Seistán; the Helmund is the largest and most important of these rivers.

The third drainage area is that of the Aralo-Caspian basin, to which the Oxus, the Balkh-áb, the Murgháb, and the Hari Rúd (Tejénd) belong. Of these consider-

able rivers only the Oxus reaches a defined lake basin, namely, the Aral sea; the remainder loose themselves in the sands and swamps of the Central Asian steppes.

Nearly all the rivers of Afghanistán have had the same history. They date back to late miocene times, since which period they have scooped out deep gorges and valleys whilst the country was gradually being laid into great anticlinal folds. Consequently they have nearly all of them formed fine examples of transverse valleys, which belong to the most characteristic features of Persian or Afghan landscapes.

Work done in Afghanistán.

As will be seen from the annexed map, the greater part of Afghanistán is geologically still a *terra incognita*. All the mountainous country from the Sulimán range to the Hazarajat including the Zhob valley, has never been visited by a geologist. The Upper Hari Rúd, the Firozkohi country, and a large portion of the Northern Hazarajat are unknown to us geologically. So is the Taimuni country and the valleys which descend from the Siah Koh. During the second Afghan campaign, 1880, I reconnoitred the route from our Indian frontier to the Helmund, including the country south-west of Quetta. Afterwards (in 1883) I had the good fortune to accompany the Takht-i-Sulimán expedition under General T. G. Kennedy, C.B., and so was able to visit the highest part of the Sulimán range, which I found to be a stratigraphical continuation of the hills west of Dera Ghazi Khan, which have been described by Dr. W. T. Blanford. Later on, in 1884, 1885, and 1886, I was attached to the Afghan Boundary Commission, and examined the entire west and northern frontier of Afghanistán, together with Eastern Khorassan and the greater part of Afghan Turkistán, and was able to reconnoitre one section from the Hindu Kúsh to India. The outlines of the geological results thus arrived at are laid down in my published "Field-notes" in the Records. In the following pages I intend to summarize these results shortly. The geological literature relating to Afghanistán is extremely limited. I have already given lists of previous authors on matters connected with the geology of Afghanistán in former papers;[1] it would be superfluous to again review this literature, as I shall have to do that when fully discussing the geology of Afghanistán in my forthcoming report.

The annexed table will show the formations met with in the examined area of Afghanistán and Khorassan and their distribution. Since the publication of my "Field-notes" in the Records, some of the leading fossils of several formations have been examined by Dr. F. Noetling, and in consequence the "*Red grits*" had to be separated from the jurassics, with the uppermost portion of which I had previously identified them, and they are now included in the neocomian.

[1] Mem. Geol. Surv., Vol. XVIII; Records Geol. Surv., Vol. XVII, pt. 4, p. 177; *ib.* Vol. XX, pt. 1, p. 18.

Groups.	…rom Sibi to Kan-	Kabul.	Sulimán range.
Recent . . .	Blow… nd of the Regis- allu… ower Helmund, … deposits.	Reg-i-Rowán near Kabul; alluvial deposits, &c.	Recent fans of rivers; alluvial deposits, &c.
Upper Pliocene .	Loes… eds of the Hel- plai… breccia deposit …alleys; laterite …ahar.	Gravel terraces of the Ghorband valley of Kabul, the Lataband, &c., &c.	Indus gravel beds on the east slope of Sulimán range.
Lower Pliocene .	…e and gravels …ht coloured clays …n valley, Quetta …urhood and Nari	Sandstone (upper Siwaliks) of Kabul river valley near Gandamák, &c.	Sandstone, clays, and conglomerates of upper Siwaliks, fringing the east slope of the Sulimán range.
Upper } Miocene . Lower }	Sand… nea… ? ? .	? ?	Sandstones, clays, marls, &c. (Blanford, lower Siwaliks). Nari sandstone, &c. (Blanford).
Eocene . . .	Num… beds . . twe…	?	Olive clays, shales, sandstones, &c., with nummulitic limestone.
Upper } Cretaceous Middle }	Whit… ic limestone of …ar, Shah-Mak- …ge, &c. Inoce… ston… Kel… Trig… taceous breccia Tak… conglomerate. Kel…	Upper cretaceous limestone of the Lataband range, &c. Afridi hills. ?	Hard whitish sandstone grit dark grey limestone passing downwards into dark limestone shales.
Neocomian . .	Red ? Má… Fira… ran…	Red grits of the Lataband range., &c.	
Jurassic, &c. . .	Black ? Zor… wes… Lime… ? the Kh…		Dark shales of the hills west of the Takht-i-Sulimán ?
Rhaetic . . . Trias and . . . Permian ? . .	Gree… ? ? pas… ?	? Altered rock with graphitic Seams of the Hindu Kúsh and the Górband valley.	
Carboniferous . .	Carb… ? Yal…	Altered limestone of the Gorband valley; Lithodendron limestone of the Safed Koh; hills near Khaiber mouth west of Peshawar.	
Sub-carboniferous .	Deh… ?		

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Upper Miocene .	Sands near	?	?	Sandstones, clays, marls, &c. (Blanford, lower Siwaliks).
Lower Miocene .		? .	?	Nari sandstone, &c. (Blanford).
Eocene . . .	Num twee	beds . .	?	Olive clays, shales, sandstones, &c., with nummulitic limestone.
Upper Cretaceous	Whit	ic limestone of ar, Shah-Makge, &c.	Upper cretaceous limestone of the Lataband range, &c. Afridi hills.	Hard whitish sandstone grit dark grey limestone passing downwards into dark limestone shales.
	Inoce ston Kel			
Middle Cretaceous	Trigo Tal Kel	taceous breccia conglomerate.	?	
Neocomian . .	Red Má Fira ran	?	Red grits of the Lataband range., &c.	
Jurassic, &c. . .	Black Zon wes	?		Dark shales of the hills west of the Takht-i-Sulimán ?
	Lime the Kh	?		
Rhaetic . . .	Gree pa	?	? Altered rock with graphitic Seams of the Hindu Kush and the Górband valley.	
Trias and . . .		?		
Permian ? . .		?		
Carboniferous . .	Carb Yal	?	Altered limestone of the Gorband valley; Lithodendron limestone of the Safed Koh; hills near Khaiber mouth west of Peshawar.	
Sub-carboniferous .	Deh	?		

General geological features.

It will be seen that the older rocks (palæozoic and mesozoic) are met with chiefly along the great Central Asian watershed, the main axis of Afghanistán. Strips of these rocks occur also at a few localities north of the main axis, and some doubtful and unfossiliferous rock groups in the Kabul district may possibly also be of older date than cretaceous. The rest of Afghanistán is covered with a thick skin of cretaceous rocks, the upper beds of which are often found to rest unconformably on the underlying older mesozoic strata. Large areas on the western and northern margin of Afghanistán are covered by tertiary strata.

Structural outlines. Afghanistán.

The main axis itself with the country north of it is part of a regular system of flexures,[1] closely compressed near the main axis, but gradually increasing in width towards the north until they become gently undulating waves and widely spread flats towards the centre of the Turkomanian area.

A similar feature is observable on the Indian side of the great watershed. The spurs which I crossed between Quetta and Kandahar not less than the ranges lying between the Hindu Kúsh and Peshawar together with the Sulimán range are nothing but portions of flexures, and it may be inferred therefore that all the highlands of the Hazarajat and Ghazni down to our frontier show much the same structure as the ranges north of the Afghan watershed.

Central Asia and Persia.

All the formations met with in Afghanistán are also found spread over the greater part of Central Asia. The main axis of Persia which forms geographically a continuation of the Afghan watershed, resembles the latter also in its geological structure. The palæozoic and older mesozoic rocks are only met with in strips near the main axis and are elsewhere hidden by cretaceous and tertiary formations. The latter cover by far the greatest area in Turkomania and Russian Turkistán, Bokhara, &c., and only along the eroded base of synclinals older rocks appear. (Mushketoff's Turkistán.)

Carboniferous and older rocks.

Beds with true carboniferous forms have been found from the Araxes in Armenia to Central Afghanistán. They form narrow strips at the base of the older mesozoics, and as such they have been traced in a more or less uninterrupted zone along the Central Asian watershed. In some places in Persia they overlie some strata which have yielded fossils of rather devonian than carboniferous aspect, and it is possible that perhaps the entire palæozoic series will be found to exist. The same rocks extend into Russian Turkistán, where they crop up from beneath the covering of mesozoic (chiefly cretaceous) formations. Limestones and shales which contain apparently the same fauna have long been known to exist in Kashmir[2] and the Himalayas, and it seems therefore probable that all these carboniferous "islands" belong to the same widely spread formation and have been deposited in the same continuous sea. The dark limestone with *Productus* of Robat-i-Pai near Herat is both palæontologically and lithologically identically the same as the *Productus*-limestone of Spiti and the Central Himalayas generally.

[1] Records, Vol. XIX, p. 236.

[2] See Lydekker's Kashmir: Mem. Geol. Surv. India, Vol. XXII.

I have myself traced it from the Binalud range in Khorassan through the Yaktán hills and the Doshakh range to the slopes of the Davendar east of Herat, and met with it again near Saighán north of Bamián. The dark limestones of the Hindu Kúsh [1] and Kabul (Jagdalak) I have provisionally identified with the carboniferous, and it appears likely that the latter is only an outlier of the Attock slate series, in which possibly some of the older palæozoics may be found.

It is remarkable that nothing older than upper mesozoic formations have been discovered in Southern Afghanistán and the Sulimán range.

Plant-bearing series. Permo-trias and jurassic.

Above the carboniferous group and conformable to it an extensive and continuous series of strata occurs not only in Persia and Armenia where they were noticed long ago, but also in Afghanistán. They form a more or less continuous belt of strata, closely connected with the underlying carboniferous group, and distributed along the entire distance from the Araxes in Armenia to the Hindu Kúsh, therefore following more or less the line of the great Central Asian watershed.

Whereas the carboniferous group consists of entirely marine deposits, the overlying strata bear the character of having been precipitated close to a coast-line; marine beds alternate with purely freshwater ones or with littoral formations containing plant-remains and coal-seams.

The thickness of the group varies very largely from a few hundred feet (Herat) to many thousands, as for instance in the Saighán section.

The fossil contents of the series will have to be worked out in detail hereafter; at present so much is certain that it rests on beds with a carboniferous fauna and is conformably overlaid by neocomian strata and therefore represents the permian, trias and jurassic formations.

Of these the last have furnished many fossil remains, both marine and terrestrial (plants). The triassic group is well characterised throughout by both plant and marine remains; the oldest fossil identified being a *Halobia* species, which I found near Chahil north-west of Saighán in Afghan Turkistán. The lowest trias is at that place hidden by upper cretaceous deposits. Further southwards the series crops out again from under its mantle of cretaceous limestone, and I found greenish grey shales (altered by granite intrusions) with anthracitic seams and a conglomerate with greenish matrix which group of strata rests conformably on the carboniferous limestone and even partially alternates with the latter.[2] I believe this formation to be the same as the carbonaceous shales and conglomerates of the Kholi Biaz [3] near Herat, and also to be identical with the hard greenish sandstone and shales which rest conformably on the carboniferous near the Doshakh peak (Herat valley) and near Gulistan and Jaghárk south-west of Mashhad in Khorassan.

It appears probable that the series between the carboniferous limestone of Bamián and the *Halobia* beds of Chahil is in Afghan Turkistán continuous below the unconformable cover of upper cretaceous limestone, and that therefore

[1] Records, Vol. XIX. pt. 4, p. 240, and Vol. XX, pt. 1, p. 22.
[2] Records, Vol. XIX, pt. 4, p. 240.
[3] Records, Vol. XIX, pt. 1, p. 54.

the upper permian and lower trias is hidden. I expect that these groups will be discovered in the "green shales" and the strata above them which play such an important rôle in the hill ranges of Northern Persia. They may also be found in the deeply eroded river valleys of the upper Balkh-áb and the highlands of the upper Hari Rúd, which I could not visit.

The same formation of littoral deposits is found in many localities in Russian Turkistán, where they also contain coal-seams as in Afghanistán and Persia. The formation bears entirely the character of being deposited along a coast, the outline of which nearly corresponds with the present direction of the hill ranges which begin in Armenia, extend through Northern Persia (the Elburz), through Khorassan, and finally divide Afghanistán into two separate drainage areas. The sea in which this formation was deposited must have been a shallow one, as is shown by the lithological character of the deposits. Numerous rivers seem to have carried not only eroded mineral material but also a large quantity of vegetable matter out to sea, for plant-remains are mingled with marine shells and carbonaceous beds and coal-seams alternate with shell limestone. In some places, probably in sheltered bays, great thicknesses of such deposits were laid down and large coal-seams have been formed, as for instance north of Saighán in Afghan Turkistán (Shisha Alang, Chahil, &c. [1])

Sufficient data are now available to show that this littoral development of the permo-triassic series is uniformly the same over a great part of the Elburz ranges of Northern Persia, in Khorassan, Northern Afghanistán, and over a large portion of Russian Turkistán. This area is flanked on each side by a succession of permo-triassic strata of purely pelagic character. On the Araxes in Armenia [2] Abich has found beds containing marine forms which also occur at the base of the triassic group in the Himalayas. These Armenian strata may be represented in Persia and Afghanistán by the green shales and conglomerates (Saighán, &c.) which may be regarded as forming a passage from the palæozoic *Productus*-beds into the lower trias.

In the Central Himalayas I found immediately resting on the carboniferous *Productus* group a succession of beds, the bottom one of which contains forms also met with in the Araxes passage beds. In the Himalayas the entire series of the permo-trias is of marine origin.

The Central Asian facies of the permo-trias bears a strong resemblance to the Gondwana series of India, not only lithologically but also palæontologically.

The general lithological characteristics of the Gondwana series of India are that of a great thickness of sandstones and shales (with coal-seams) containing plant-remains, which begin at their base with a generally greenish coloured conglomerate, sandstone, and shales, and which ends with a great thickness of coarse-grained sandstone and grits (Mahadevas &c.).

The permo-trias and jurassic series of Central Asia is a succession of marine and littoral formations, which also begin at their base with a greenish conglomerate,

[1] Records, Vol. XIX, pt. 4, p. 243.

[2] H. von Abich: Geol. Forsch. in den Kaukas. Länd., Pt. 1, 1878.

sandstone, and shales, and ends with coarse sandstone and grits with volcanic ash beds (late jurassic and neocomian).

The middle of the series is well characterised by fossil remains, amongst which are typical triassic and jurassic marine forms, associated with plants which also occur in the middle Gondwanas (*Schizoneura*, &c.). Similarly both in the Gondwanas of India and the permo-trias of Central Asia, coal-seams are chiefly developed in the middle of the series.

But unlike the Gondwanas, the Central Asian series is correctly defined as regards its age; it is inclosed between carboniferous *Productus*-beds and neocomian strata. The lowest beds of the series are partially alternating with the carboniferous group, and the upper portion of the plant-series is passing gradually into the marine neocomian horizon. The ages of several of the middle and upper zones of the series are accurately fixed by their marine fossils. We have therefore an extensive series of strata, the lowest beds of which may be regarded as carboniferous and the uppermost as of upper jurassic and neocomian age, and of which only the permian and lower trias is destitute of determinable organic remains. It is interesting to notice that just these lowest beds, which are closely connected with and alternate with the carboniferous group, resemble lithologically the lowest Gondwanas or Talchirs in some important characters and like them contain impressions of *Vertebraria*-like forms.

From the clearly establised upper trias (*Halobia lommeli* horizon) to the neocomian, the succession of fossiliferous strata is continuous.

The upper plant-shales yielded middle and upper jurassic marine fossils; lithologically they resemble the Spiti shales of the Himalayas, and they alternate and pass into the "red grit" group, the upper portion of which is undoubtedly neocomian as is proved by their fossil contents.

Cretaceous group.

The cretaceous series forms wide-spread deposits in Afghanistán and indeed over a large area of Central Asia. A large portion of Afghan Turkistán with the hills (Tirband-i-Turkistán, Koh-i-Bába, &c.) is formed of cretaceous rocks. West and north-west the cretaceous group extends in strips through the Herat province into North-eastern Khorassan. And south of the great Afghan watershed and as far as the Indian frontier I believe cretaceous rocks will be found to form most of the ranges, which run in long lines, south and south-west from the Koh-i-Bába and the Kabul highlands.

I have found cretaceous rocks in great force in the section between the Hindu Kúsh and Peshawar, whilst the south-western extensions of the Central Afghan ranges —the spurs which extend to Kandahar, the Khojak range, and Quetta—are also composed of upper cretaceous rocks. So also is the principal chain of the Sulimán range, of which the Afridi hills near Peshawar form a northern continuation. In Khorassan and Northern Persia the cretaceous formation forms great ranges and plays an important part in the structure of the chains of mountains which skirt the northern frontier of Persia. In Central Asia the upper cretaceous covers a large area, and hides nearly all the older formations, which appear only in isolated patches, where the overlying cretaceous mantle has been denuded. In the sections of the central Himalayas and Kashmir the cretaceous formation is comparatively rare, but it is probable that further to the northwards and north-east great tracts of the Central

Tibetan ground is formed of cretaceous rocks. There is evidence[1] that cretaceous rocks are *in situ* in the neighbourhood of Lhassa.

Several horizons of the cretaceous group are represented in Central Asia. The most complete sections I met with in Khorassan where apparently all horizons from the neocomian (with marine fossils) to the upper cretaceous *Exogyra*-limestone are represented.

Further eastwards, in the Herat province and in Afghan Turkistán, the middle cretaceous seems altogether wanting in most of the sections, and in that case the upper cretaceous *Exogyra*-limestone rests unconformably on the jurassic or older groups of the plant-bearing series.

Tertiary system.

In Afghanistán and Central Asia tertiary formations form wide-spread deposits. Along the southern, south-western, and partly the western boundaries Afghanistán is skirted by tertiary and sub-recent deposits, which form most of the deserts and great plains of the lower Helmund drainage. Tertiary deposits also fill the Herat valley and extend far into the valleys of Eastern Khorassan. Badghis, drained by the Hari Rúd, the Kushk and the Murgháb rivers, the Maimana province, and the greater part of Afghan Turkistán with the Oxus valley, form part of the enormous Aralo-Caspian basin, which is for the most part filled with tertiary and later deposits. Only along the southern edge of the Badghis and Turkistán tertiary area older beds of this system crop up, namely, eocene and miocene marine strata. Small patches of such are seen inclosed in synclinal basins high up in the highlands of Saighán and Bamián, and a belt of older tertiaries also crops up on the Oxus near Kilif and Khamiáb.

The deposits on the north slope of the great Afghan watershed differ in many respects from those which form a fringe to the cretaceous Sulimán range and compose most of the Búgti and Marri hills east of Quetta.

In the Herat valley, Eastern Khorassan and the steppes of Badghis, Maimana and Turkistán the great divisions of the tertiary series are :—

		6. Blown sands and recent alluvium.
Upper	Pliocene	5. Loess deposits and old fans.
Lower		4. Freshwater deposits with plants and land shells.
Upper	Miocene	3. Estuarine deposits.
Lower		2. Marine miocene beds.
		1. Eocene.

Eocene.

The eocene formation has only been proved to occur in one locality, namely, near Nishapur, in Khorassan, where nummulitic limestone occurs. In Badghis and Turkistán the upper cretaceous limestones are overlaid by marly limestones in thinner beds and sandstone which are again overlaid by fossiliferous miocene strata. This intermediate formation, which is of considerable thickness, I believe to represent the eocene horizon.

Miocene.

The miocene formation, both lower and upper, is of wide-spread extent in Central Asia, and to it belong nearly all the salt and gypsum deposits, many of which are worked. I believe the Afghan miocene formations to be essentially the same as the gypsiferous series of Persia described by Loftus, Abich, Grewingk, &c., and which forms

[1] O. Feistmantel: Records Geol. Surv. India, Vol. X, p. 21.

such large deposits in Western and North-western Persia, Armenia, and the Caucasus.

North of the Afghan watershed, older tertiaries appear along the north slope of the Barkhút range (the Paropamisus of our old "Turkistán" maps), seem to fill the Murgháb (Ferozkohi) synclinal, and may be traced in patches north of the Koh-i-Bába (Mathár, Bamián). North of the anticlinals of the Tirband-i-Turkistán they crop up again in a long fringing line, resting conformably on the upper cretaceous limestone and strike east from Tashkhurghan. Due east of the latter locality, miocene strata (salt-bearing) appear at Khánabád in Badakhshán, where probably the two lines of tertiary synclinals join. The area east of Khánabád with the Hindu Kúsh and Kafiristán is chiefly composed of metamorphic rocks,[1] which may have formed part of a great crystalline massif. On the Oxus and beyond, in Bokhara, older tertiaries again crop up, and it appears that in Central Asia these rocks participate largely in the formation of the hill ranges.

Tertiaries south of the watershed.

How far the older (marine) strata of the tertiaries of Turkistán resemble the eocene and miocene formations of Sind and Biluchistán will have to be determined hereafter, when the fossil contents of both have been compared.

South of the great Afghan watershed older tertiary deposits are found in the neighbourhood of Kohat, whence they strike southward, fringing our frontier and the Sulimán range. Probably the large triangular area between the Sulimán range, the Búgti hills, and the line which connects the Pishin valley with Kohat will be found mainly to be formed by tertiary deposits. Upper tertiary formations cover a large area in Southern Afghanistán and the neighbouring ground. The frontier belt of Afghanistán and Biluchistán with many of the wider valleys inside the hills are made up of later tertiaries.

Changes during and after miocene times.

During the miocene period began the changes in the distribution of land and sea which continued during later tertiary times and are still going on. The miocene sea gradually retreated from the western shores of the Afghanistán (Badakhshán, Kafiristán massif) continent, and large estuaries began to form along the coast-lines in which the latter miocene deposits were laid down. Such is evidenced by the Bamián and Mathár, the Tashkhurghan and many other sections in Central Asia.

The change of conditions must have been very gradual, for there is no break in conformity visible between the drab clays and shales of the estuarine upper miocene and the densely bright coloured, red, and purple clays, sandstones and shales with conglomerate of the upper tertiaries, which is a purely fluviatile and lacustrine formation.

These conditions find their analogue in the Biluchistán sections, where the change from the miocene (Gaj) beds into the upper miocene (lower Manchhars) is equally gradual. The upper Manchhars (upper Siwaliks) of Sind and Biluchistán may be compared with the Turkistán freshwater pliocene. The lithological resemblance of the latter with the upper Manchhars of Sind or upper Siwaliks of the trans-Indus range is remarkable.

[1] Dr. Giles: in Ann. Rep., Records, Vol. XX, pt. 1, p. 9.

Changes continued to recent times.

The same changes, *i.e.*, the retreat of the miocene sea from the tertiary continent and finally its separation into several lake-basins (the Aralo-Caspian), continued long after the deposition of the estuarine strata along the margin of the Turkistán highlands.

Aerial formations. Loess.

With the change of outline of these lake-basins and the diminution of rainfall and consequent decrease in volume of the drainage flowing from the Afghan highlands, begin to appear aerial formations, which near the margin of the hills are seen to be intercalated between the fluviatile deposits of the upper tertiaries. In pliocene times already began the accumulations of vast deposits of loess, whose aerial origin is clearly shown in the scarps which every Turkistán river cuts through it in its northward flow.

The accumulation of loess is still going on over a large portion of Central Asia including Northern Afghanistán. The steppes owe their origin to the nature of the recent deposits of loess. Every one of the wider valleys of Eastern Khorassan and the Herat valley are partly filled with loess accumulations. The grass-covered downs (Chúll) of Badghis, Maimana, and Afghan Turkistán are nothing but wide-spread loess deposits.

In South-western Afghanistán the conditions are similar. There the gradually drying-up inland basin of the Helmund is under the influence of air-currents which deposit vast thicknesses of loess on both banks of the Helmund and in Seistán; they rest on stratified deposits of clay, sands and conglomerate, which are lithologically identical with the Chúll deposits of Turkistán.

For the description of the Biluchistán ranges,[1] the Búgti hills,[2] and the Sulimán range[3] I refer to the descriptions given in the publications of the Geological Survey of India.

Igneous rocks.

I found it impossible to separate the various intrusive igneous rocks on the small scale map which accompanies this paper. I believe the igneous rocks of Afghanistán and North-eastern Khorassan belong, broadly speaking, to four different epochs. They are :—

4. Trachytes and rhyolites of Khorassan	Tertiary.
3. { Trap	} Eocene.
3. { Syenitic granite	} Eocene.
2. Trap	Jurassic and neocomian.
1. Trap and melaphyre	Permian.

1. The oldest igneous rock of Afghanistán I believe appears as interbedded trap and melaphyre in the lowest beds of the plant series, which I have correlated with the permian of the Araxes and the Himalayas and the Talchirs of India. They are well seen in the Herat sections and in the north-western extension of the Yaktán range of Khorassan.

2. Enormous outbursts of traps and porphyritic rocks appear as intrusive and partly interbedded masses in the red-grit group. They are particularly well seen

[1] W. T. Blanford: Mem. Vol. XX, pt. 2. C. L. Griesbach: Mem. Vol. XVIII.

[2] W. T. Blanford; Mem. Vol. XX, pt. 2.

[3] W. T. Blanford: Mem. Vol. XX, pt. 2. C. L. Griesbach: Records, Vol. XVII, pt. 4, p. 175.

in the Herat province; the Ardewán, Marbich, Band-i-Bába, and Zurmust passes lead over sections through these late jurassic traps. The upper beds of the red-grit group are almost entirely made up of fragments of igneous rocks and great thicknesses of ash-beds swell out the total of this group enormously.

3. Structurally the most important of the igneous rocks of Afghanistán are the syenitic granite and trap outbursts of post-cretaceous times. They form dykes and bosses in Khorassan and the Herat province (Davendar) and form most probably a continuous belt through Central Afghanistán. I met them again in great force in the Hindu Kúsh, which, with its parallel chains north and south, is nearly entirely composed of these rocks.

They are seen to penetrate the upper cretaceous limestone, which is then frequently converted into white marble near the contact.

I believe the outburst to date either from late cretaceous or eocene times.

To it belong the post-cretaceous syenites and traps of Kandahar and the desert south of the Helmund.

4. In Eastern Khorassan appear trachytes and rhyolites (north-west of Nishapúr) which have intruded between strata of nummulitic limestone and therefore can hardly be older than middle tertiary.

Summary. The following facts may again be summarized.

1. The carboniferous group shows great points of resemblance, both lithologically and palæontologically, over the entire distance from the Caucasus to the North-west Himalayas. It is a purely marine formation, and pelagic conditions seem to have prevailed in the Caspian region, Northern Persia, Afghanistán, and the Himalayan area.

2. At the close of the carboniferous period began a shallowing of the sea over the greater part of Central Asia, including Northern Persia and Afghanistán, which more or less continued to neocomian times, when the sea altogether retreated from large tracts of Central Asia, including Afghan Turkistán.

During that time littoral deposits were laid down along a coast line which seems to have agreed more or less with the present direction of the Central Asian watershed.

In the adjoining areas, of Asia Minor and the Himalaya, pelagic conditions continued.

3. In upper cretaceous times a great overlap of the sea began and extended to lower miocene times.

4. After the deposition of the lower miocene the sea began to retreat gradually from the coast-lines, not only in the Central Asian area, but also in Sind and Biluchistán, and estuarine and freshwater deposits were being laid down conformably on the marine miocene beds.

The retreat of the miocene seas was continued in late tertiary times and in fact the same changes are still proceeding at this moment. In place of the estuarine deposits huge accumulations of freshwater and aerial formations took place over the greater part of Central Asia, Persia, and our Sind frontier.

Notes on the Microscopic structure *of some specimens of the* Rájmahál *and* Deccan traps, *by* COLONEL C. A. MCMAHON., F.G.S.

(Received December 23, 1886.)

Igneous rocks of the Rájmahál group: Augite-Andesites.

1—434[1].—Amygdaloid. Motijharna.

This rock has been considerably decomposed by the percolation of water, and has been reduced to a condition that reminds me very much of the traps of Mandi and Darang, in the Himalayas. The matrix of the amygdaloid consists of a network of felspar prisms, starred about in a muddy-looking, and almost opaque, base of greenish-brown colour. In reflected light this is seen to be studded at regular intervals with fine fibres of magnetite which radiate in all directions. The slice is dappled here and there with an amorphous red product; remains of augite are also visible, but this mineral has been altered almost out of recognition.

All the felspar belongs to the triclinic system, and none of it appears in the form of porphyritic crystals

1—441.—Amygdaloid. Dubrajpur.

The matrix of this specimen is composed of triclinic felspar, augite, and magnetite. The felspar occurs both in porphyritic crystals, and in small but regular prisms. If the former were left out of consideration, the smaller felspars and the augite would be in about equal proportions to each other. The augite is in a granular condition; that is to say, it does not present crystallographic outlines.

A zeolite, varying from white to yellowish-red in colour, stops the amygdules, and invades the substance of the rock, forming very numerous *lacunæ*, with strongly marked marginal borders. The inner portions of many of the large felspars have also been replaced by this product of decomposition. With this exception the rock presents a fairly fresh appearance.

Among the felspar crystals, crosses formed by baveno twins are common; and whilst twinning on the albite plan is visible in nearly all the felspars, pericline macles are also to be seen here and there.

Augites occur in both these slices in somewhat large crystals as well as in smaller granules, and a few of them present rather good external shapes. Twinning is to be observed in some of them, but it is not at all common.

The augite and felspar appear, on the whole, to have crystallized simultaneously, but instances are not wanting to show that some individuals of both minerals crystallized in advance of others. Thus these slices present examples of twinned and well-formed augites, and groups of augites, imbedded in rather large felspars; and also of augites formed upon felspar prisms. In other cases the growth of the latter mineral has apparently been stunted by the formation of crystals of pyroxene by their side.

[1] The numbers given are those of the Geological Survey of India.

This feature, *viz.*, the simultaneous formation of augite and felspar, and the enclosure of augite by felspar, and of felspar by augite, was noted as a characteristic of the Bombay basalts in my paper on those lavas, see Records XVI, pp. 43, 46, and plates. I may further draw attention to the fact, in passing, that the inclusion of groups of well-formed augites in large felspars, noted above, shows conclusively that we must not jump to the conclusion that all large felspars porphyritically imbedded in a finer grained ground-mass necessarily belong to a different "generation," and had their birth considerably in advance of the smaller crystals of the ground-mass. The porphyritic and zoned felspars were doubtless formed before the small prisms of felspar; but the interval between them need not have been great in point of time, and the birth of both may have been the result of cooling when the lava began to consolidate after it had flowed from the mouth of the volcanic crater. At any rate, it is clear that some small crystals of augite were formed in the magma prior to the crystallization of the large felspars, and we may reasonably infer that the crystallization of the whole mass had begun when the porphyritic felspars were formed. This inference is also supported by a further fact observed in slice No. 436; namely, that there is a gradation from the felspars of largest to those of smallest size, and not an abrupt transition from large porphyritic felspars to small lath-shaped prisms.

In No. 436, magnetite is very abundant. The products of decomposition are, in No. 436, a greenish-brown; and in No. 440, a substance that is of greenish-brown colour in some places, and yellowish-red in others. This cannot be traced directly, or indirectly, to the alteration of augite; on the contrary it fills the rôle of a glassy base, and possibly represents the uncrystallized residuum. The pyroxene is very fresh, but occasionally inner portions of the large felspars are replaced by the secondary product of decomposition, above alluded to, which is not green enough to be called viridite. These probably represent portions of the base caught up in the felspars. Occasionally in No. 436 the greenish-brown matter appears in rounded forms, suggestive at first sight of pseudomorphs after olivine, but this appearance is, I think, delusive; and the hypothesis that might be based on it is refuted by the general behaviour of this greenish-brown matter and by other considerations. This greenish-brown material apparently forms the base in which the constituent minerals of the rock are imbedded. Moreover these slices contain no serpentine, or serpentinous viridite, and no trace of *Maschen Structur* due to the deposition of opacite, or magnetite, round the edges or along the cracks in olivine crystals, which often betray the original presence of that mineral after its substance has been converted into serpentine. The conclusion at which I have arrived, after a careful study of the Rájmahál slices is that there is not a trace of olivine in any of them.

1—436 Rájmahál Hills. 1—440. "Ball trap." Motijharna.

Viewed macroscopically these are very basaltic-looking specimens, and they would no doubt ordinarily be called basalts. Under the microscope they are seen to belong to exactly the same class of rock as No. 441, described above. Indeed, the difference between them is not one of original structure, or composition; but consists entirely in the relative progress of decay. The amygdaloid was more exposed to the infiltration of water than the less porous lavas, and has necessarily suffered more. As a consequence the zeolites so abundant in the amygdaloids are entirely absent from these two specimens.

As in No. 441, the two rocks under description consist of a mixture of triclinic felspar, augite, and magnetite; and as in the Dubrajpur lava, porphyritic crystals of felspar are imbedded in a ground-mass composed of small prisms of that mineral, and granular augites. In No. 440 the crystals of the ground-mass are relatively smaller, as compared with the large felspars, than in No. 436. Zonal structure, characteristic of the andesitic type of rocks,[1] is common in the porphyritic felspars.

Enstatite-hornblende-diorite.

1—446. Betia Hill.

This is a very interesting specimen. It is composed of the following minerals, namely, triclinic felspar, enstatite, hornblende, magnetite, quartz, apatite, and a little mica. In structure it is perfectly granitic and holocrystalline.

The felspar, judging from its optical characters, is labradorite. It is considerably "schillerized" (Judd), and the included matter is arranged in such regular lines, that in some cases, when low powers are used, it imparts the appearance of fine striation to the crystals.

Occasionally the felspar is so crammed with colourless globulites, and microliths, as to impart a graphic appearance to it similar to some of the felspar in the Dalhousie and Sutlej Valley gneissose granites (*query*, is this eucryptite, or an allied mineral —see Dana's 3rd Appendix, p. 113); at other times rounded microliths of hornblende occur.

The enstatite is about as abundant as the hornblende; it is intimately associated with it, and sometimes it is surrounded by a fringe of the latter mineral.

Magnetite is abundant, and is usually imbedded in the hornblende.

There is not much quartz; and it is evidently the residuum left after the crystallization of the other minerals. It contains some liquid cavities with bubbles.

Apatite is abundant, and is present both in the form of slender microliths and also in good-sized prisms. Mica cannot be detected in the thin slice, but a small packet of undoubted mica was observed on a macroscopic examination of the hand specimen with a pocket lens; it is of dark reddish-brown colour, and an examination of a flake in convergent polarized light showed that it is one of the micas that used to be referred to the hexagonal system.

Andesite.

No. 14—19. Sendurgusi Hill. Sp. G. 2·65.

A compact lava of pinkish colour. It is very rough on the fractured surface, the roughness being produced by its fine-grained porosity; indeed so porous is the rock that the hand specimen, on being plunged into water, continued to give forth streams of air-bubbles for a long time. Owing to the air contained in the specimen, some of which was probably unable to escape, the specific gravity given above is, I dare say, a little too high; but the point is not material as andesites range as low as 2·54[2] and this specimen cannot be much, if at all, lower than 2·6.

[1] Judd: Quar. Jour. Geol. Soc. xlii, 426.

[2] Teall: Geol. Mag., 1883, p. 107.

No. 14—19 was collected by Mr. V. Ball, F.R.S., and it is believed to be a sample of the rock near the Simra Bungalow, described at p. 66 of his memoir on the Geology of the Rájmahál Hills (Memoirs, G. S., Vol. XIII).

Viewed macroscopically this specimen has all the aspect of a trachyte; but as the predominant felspar is certainly not orthoclase (sanidine), it must be classed with the andesites.

To prevent any mistake I had a second slice of this hand specimen prepared, but I have been unable to detect in either of the slices a single crystal of sanidine. The felspar, judged by these slices, is all triclinic; and belongs, like that of the augite-andesites, described above, to the labradorite-anorthite group. It is frequently zoned and presents examples of every form of twinning—albite twins being combined with those of carlsbad, pericline, and baveno.

The rock is composed of a mass of felspar crystals of various sizes (some being comparatively large) imbedded in a devitrified glassy base. The base is much more prominent in one slice than in the other.

The Simra andesite must originally have contained a large amount of magnetite. Some of it has been left in an unaltered condition; but the greater part has been converted into a red oxide; and it is to the presence of the latter in large quantities that the reddish-pink colour of the rock is due.

Olivine is totally absent, and augite is very sparse; being limited to the presence of a few stray, rounded, and corroded crystals. These have apparently not been formed *in situ*, as they are externally very much corroded, as if by an acid magma.

I thought it would be interesting to compare the Rájmahál specimens with the samples of Deccan traps in my possession; and accordingly sliced and examined the following, which are good typical examples from five different, and widely separated, localities.

Deccan Trap.

No. 1—A sub-vitrious lava. Antop Hill. Bombay.

A detailed description of the geology of Antop Hill and of this rock, the "black rock of Antop hill, (?) felstone" of the map which accompanies Mr. A. B. Wynne's paper, will be found at p. 36—40, Memoirs, Geological Survey, Vol. V. It is described as a "black splintery rock." "The whole rock of this hill," Mr. Wynne informs us is "of a curious compact and almost flinty kind," which "differs greatly in appearance from any of the trap-rocks commonly found in the neighbourhood;" but it "reappears at Seoree," and forms "the rock called Cross Island, in the harbour, at a distance of several miles." "Some previous observers thought it resembled an altered argillaceous deposit," but Mr. Wynne successfully combated that notion in his memoir.

Under the microscope this is seen to be a true volcanic rock. It is singularly, fine-grained—finer grained than any lava I have ever before seen; but thin slices under the microscope have none of the aspects of a basalt-glass on the one hand, or of a felsite on the other.

The rock is composed of microscopic prisms of triclinic felspar, and microscopic grains of augite, and magnetite. The microliths of felspar are well formed though minute, and they exhibit distinct fluxion structure in their arrangement.

None of the lavas of Bombay described in my paper in Records XVI, 42, come any where near this specimen in fineness of grain.

The rock does not contain any glassy base—the base being composed of extremely minute granular crystals, possessing low double refraction.

There are some porphyritic crystals of triclinic felspar, and augite, and the slice contains round holes stopped with opal, and a red and greenish substance which may possibly be analcime, or an allied mineral. The slice is also stained red here and there, in streaks, with oxide of iron. We thus see that even an extremely fine-grained, compact rock like this, is unable to resist the penetrating power of water.

No. 2.—Amygdaloid of Pukarni quarries near Harda. A favourite building stone.

This is not a very interesting rock under the microscope owing to the amount of alteration it has undergone. The remains of the magnetite, which was apparently very abundant, may still be seen dotted about through the matrix; but the principal part of it has been converted into the red oxide of iron which has made the matrix very opaque, and has given it a red colour.

The felspar prisms imbedded in the ground-mass are more or less decomposed, and replaced by white products of decomposition; the amygdules are stopped with a zeolite, chalcedony, and opal, and the substance of the matrix is invaded by free quartz and zeolitic substances. The original porous character of the rock has evidently greatly facilitated the alteration of its component minerals.

The general appearance presented by the slice in the field of the microscope is that of a net-work of felspar prisms, imbedded in an opaque brick-coloured matrix, but owing to the progress of decomposition the outlines of the felspars are not sharp or regular. No augite is to be seen.

No. 3.—Ball trap. A very common type all over the Deccan.

This consists of a net-work of triclinic felspar prisms, granular augite, and magnetite, in which ground-mass large crystals of plagioclase are porphyritically imbedded.

The rock, under the microscope, has a very fresh appearance; the felspar and augite, in particular, looking remarkably so; nevertheless it appears to have suffered considerably from the agents of decomposition, for calcite is present in considerable abundance, whilst limonite, and hæmatite, have not unfrequently replaced the magnetite.

An orange-coloured substance is rather abundant, and forms a striking object in these slices, regarding which it is difficult to speak very positively. At first sight it looks like a mineral, but it plays the rôle of a glassy base; it is absolutely without external form or cleavage, and nearly all of it is inert between crossed nicols. Occasionally it polarises feebly in its own natural colour. Closely allied to this is a dark-green substance, which in polarised light is perfectly isotropic. Soaking in hot hydrochloric acid sufficiently long to completely remove the hæmatite, and magnetite, makes scarcely any impression on the orange substance, and little on the green, that is to say, it removes the green colour, and converts the orange into a dull red, but leaves a glass behind absolutely inert in polarised light.

On the whole, then, I have come to the conclusion that both the bright-orange and the dull-green substances, represent the original magma, or glassy base of the rock, and that they owe their mineral appearance to iron colouration.

The larger felspar crystals contain glass inclusions with fixed bubbles. The felspar appears to belong to the labradorite-anorthite group.

No. 4.—This specimen was labelled 'average basalt: One Tree Hill[1] quarries. Belgaum.'

It is a perfectly compact trap, of dark-grey colour.

Under the microscope this is seen to be a fine-grained rock, composed of prisms of plagioclase felspar and granular augite, with some magnetite; in which ground-mass comparatively large crystals of triclinic felspar are porphyritically imbedded. Some of the grains of augite are of considerable size, but none of them show any approach to external crystallographic form.

The remains of the original glassy base, in part of green colour, and in part reddish-brown, is visible here and there. What I take to be the glassy base exhibits undulating marginal lines of colour that follow the borders of the bounding minerals. This appearance has been described by Zirkel in his Microscopical Petrography, p. 234, and depicted in Plate XI, fig. 1, of that work. Zirkel described this substance as the globulitic base of an altered basalt, metamorphosed into amygdaloidal nests. In the case of the Belgaum rock, however, the metamorphism can hardly have proceeded beyond the colouration of the glassy base, for boiling in hydrochloric acid makes little or no impression on it. It has no action on polarised light.

The felspar belongs to the labradorite-anorthite group.

No. 5.[2]—From a dyke more than 100 yards wide, in the Sátpura basin of Gondwána rocks; believed to be Deccan trap, which appears to have once covered the Gondwánas of the Sátpura region (Manual, Geology of India, Part I, pp. 213, 214).

This is a large-grained, perfectly holocrystalline dolerite, exhibiting no trace of a glassy base. Indeed in structure this rock approximates to a gabbro. (Judd, Q. J. G. S. xlii, 62.)

The whole of the felspar is triclinic, and the prisms of which it is composed are massed together solidly, rather than in lath-shaped forms. The augite is granular, but massive; and its mutual relation to the felspar is more granitic than in a true lava. Apatite, magnetite, or ilmenite, and some iron pyrites occur in the rock. The felspar is much altered in places, and the augite is changed along cracks into a fibrous substance.

General Remarks.

For the whole of the specimens described in this paper I am indebted to Mr. Medlicott, Director of the Geological Survey of India. The Deccan Trap samples were received some years back; the Rájmahál ones recently.

[1] Foote: Mem. Geol. Sur., India, XII, p. 182.

[2] Survey number 43-2. The specimen was taken from the bottom of the deep gorge about a mile west of Koréngla Hill (2,221 feet, Lon. 78° 42′. Lat. 22°, 34′), on the same dyke, may be 900 feet higher than the gorge. This great dyke, and several others in this field, are many miles in length, and suggest fissure-eruption, rather than volcanic vents. From Korángla a great loop-dyke emerges to the north, and joins again some 5 miles to the west, forming a bow-shaped ring round the Mirakota plateau, of Mahadeva sandstone.—H. B. M.

All the Rájmahál rocks described in the preceding pages, except No. 446, are true lavas. No. 446 (Betia Hill), on the contrary belongs to the plutonic class of igneous rocks; and its perfectly granitic structure shows that it was consolidated at some distance from the surface. Whether it formed part of a dyke; or whether the mass from which this sample was taken constituted the root of one of the Rájmahál craters, it is impossible to say from the examination of this hand specimen. I have not been able to trace any notice of Betia Hill in the Manual of the Geology of India, or in Mr. Ball's memoir on the Rájmahál Hills. I infer from the observations at page 170, Manual, Part I, that Betia Hill was not suspected to be the root of an old volcano; but as the specimen was labelled "*basalt*" by whoever collected it, it might be worth while for some future observer to take another look at Betia Hill. The trap is certainly not a lava. It is a diorite of granitic structure, and very probably indicates the site of one of the old Rájmáhál volcanoes.

A similar remark applies to the Deccan trap specimen from the Sátpura Hills. Though its structure is not so decidedly granitic that the rock can be classed as a plutonic one; nevertheless, it is perfectly holocrystalline and *appoximates in structure* to a gabbro. Clearly the consolidation of the rock, and the crystallization of its component minerals, took place under considerable pressure. The sample was taken from a dyke of great width, shooting up through the Gondwána rocks, which seem nearly surrounded by, and to have been formerly overlain (Manual pp. 213, 214) by Deccan trap; and we have here, I should think, the site of one of the missing volcanic *foci*. Doubtless when the microscopic examination of the Deccan traps in the laboratory goes hand in hand with their close and detailed examination in the field, the general absence of traces of the volcanic vents from which the Deccan and Rájmahál traps were poured forth will no longer be complained of.

No connection between the Deccan and Rájmahál traps has been traced (Manual, xli); and the suggestion of some geologists that the "Rájmahál traps of the upper-Gondwána period, and the Deccan traps are portions of one continuous series of outbursts," is not favoured in the Manual: on the contrary, the conclusion is arrived at, that, "in the absence of any direct evidence, it is premature to suggest that there is any connection between the two formations, or to class them as portions of one great igneous series."

That being the state of the case, it may not be uninteresting to enquire whether the microscope throws any light on the subject. Without intending to imply any intimate connection between the two series in point of *time*, I think the study of the above described samples, though few in number, suggests the probability of their having a deep-seated common origin. The Rájmahál lavas seem to belong to precisely the same type of rock as the Deccan traps. They do not differ, for instance, from each other as the lavas of Aden do from those of Bombay; on the contrary I do not think that any one examining unnamed specimens of the Rájmahál or Deccan traps could possibly say, from any evidence revealed by the microscope, which series he was dealing with.

In all the samples described in this paper, as well as those in my previous one on the "Basalts of Bombay," the entire absence of olivine is a noticeable feature. Olivine is certainly present in considerable abundance in some Deccan traps,

and in some Rájmahál traps (Manual, Geology of India, Part I., pp. 170, 302), though it is specially mentioned in connection with the coarsely crystalline varieties; nevertheless, the entire absence of this mineral in every one of the samples from widely different localities, that I have examined,[1] is a circumstance that seems to possess considerable significance. In the face of it I may, I think, fairly infer that olivine is *generally* absent from the Deccan and the Rájmahál traps; and that when present, it is an exceptional rather than a regular, and characteristic constituent.

In view of this fact, the question arises what are these lavas to be called? They have always, heretofore, from their macroscopic aspect been termed dolerites and basalts. In my paper on the Bombay traps, I said that "a good case might be made out for classing the Bombay rocks with augite-andesites rather than with basalts" (Records, xvi.-49), though I preferred, for reasons stated therein, to retain the name that had hitherto been given to them.

Professor Judd, speaking of the rocks of Fiji (Q. J. G. S., xlii, 427), writes "although both of these rocks have the general aspect of basalts, yet, as olivine is absent from them, I follow the great majority of continental petrographers in classing them with the pyroxene-andesites. I believe this course is practically more convenient than that of extending the groups of basalt and dolerite by including in them the larger part of the pyroxene-andesites." No doubt the presence or absence of olivine is a most important fact; but alas! for the working microscopist, it is the first mineral to decay; and although the original presence of olivine may often be detected when it is going, or just gone; it cannot, I think, be detected after decay has advanced beyond a certain stage without drawing on the scientific imagination more liberally than it is safe to do.

However, as it would be useless to set up a nomenclature of my own, it would seem to follow that the rocks described in this paper, excepting only the enstatite-diorite of Betia Hill, must be called augite-andesites. The Sendurgusi Hill rock, with the aspect of a trachyte, will have to be called an andesite as it contains no sanidine.

[1] I omit from this generalization two or three slides lent me by Mr. Medlicott some years ago. I did not see the hand specimens from which they were taken, or study the slices in detail.

Some notes on the Dolerite *of the* Chor, *by* COLONEL C. A. MCMAHON, F.G.S.

[Received December 23rd, 1886.]

No. 1.—A compact dark-grey rock, very dense and very hard. Sp. G. 3·07. Batteori, Chor Mountain.

No. 2.—A compact dark-grey rock. Sp. G. 3·05. Barela, Chor Mountain.

No. 3.—A similar rock from between Barela and Sohana, Chor Mountain.

None of the above named villages are entered in the Government of India Survey Map, Sheet No. 47. Batteori is on the south side of the Chor, on the road between Nhára (Nara of map) and Tálichoag, both of which places will be found marked on Mr. Medlicott's map (Vol. iii, Memoirs G. S. I.) near the edge of the gneissose granite ("granitoid rocks" of map).

Barela is on the western flank of the Chor, at the edge of the outcrop of gneissose granite, and is, I presume, the place entered on the above mentioned maps as Banallah.

In my field journal I have noted the Batteori rock as occurring in the gneissose granite above the village, and cutting down the hill side in the direction of Tálichoag. The Barela outcrop occurs as a dyke in mica schists, within a few yards of a garnetiferous hornblende rock. This dyke is on the crest of the ridge just above the village, but another outcrop of it is to be found 500 or 600 feet below, just above the bed of the stream. It appears there between beds of felspathic and mica schists, but the outcrop is cut off abruptly at both ends, and does not extend for any distance as a continuous sheet.

Sohana is entered on both the above mentioned maps, in a line between Barela and Tálichoag. I gather from my journals that the outcrop between Barela and Sohana is in mica schist. This rock is evidently the dense trap alluded to in the Memoirs, Geological Survey, III, 42.

I have examined nine thin slices of the above rocks under the microscope, and the result shows that the trap retains essentially the same character throughout. Following the nomenclature adopted by Professor Judd in his recent papers (Q.J.G.S., xlii, 61, 62) it may be classed as a dolerite verging towards a gabbro.

The examination of thin slices under the microscope shows that the Chor dolerite is a perfectly holocrystalline rock. It is composed of triclinic felspar in the form of lath-shaped crystals (namely, small elongated prisms) imbedded in a ground mass of augite which plays the rôle of a magma, or base. Olivine, magnetite, red mica, and apatite, are also component crystals.

The felspar is all twinned on the albite plan; but pericline macles are not unfrequent and baveno twins also occur. Judging from its optical characters the felspar belongs to the labradorite-anorthite group, and more than one species would seem to be present. In one of the Batteori specimens a few comparatively large felspars occur, otherwise they are all in the form of elongated prisms matted together.

Even in the thinnest slices, the felspars are tinted a pale, reddish-buff colour. This seems to be a special characteristic of the Chor dolerite; it is common to all the

specimens described in this paper, and I have not met with any thing resembling this tint in the felspar of other rocks. It is doubtless connected with the presence of a large amount of iron in this dolerite, but the colouring matter is so finely disseminated that the highest magnifying powers applicable are insufficient to determine its source.

"Schillerization" has been set up in all the felspars, and amongst other microscopic inclusions opacite is abundant. These products of alteration, however, are very minute, showing that the process of schillerization had not extended far.

The augite is quite colourless in transmitted light, and is very fresh. It is not unfrequently twinned, but it never shows any trace of external crystallographic form. Club-shaped grains of this mineral are not uncommon.

The most interesting mineral in the rock is olivine, for it is in almost precisely the condition of the black olivines described by Professor Judd, in his paper on the Peridotites of Scotland (Q.J.G.S., xli, 382), the development of opacite, magnetite, or other iron oxide, within the mineral, being due to the process called schillerization. I may note, in passing, that when I showed one or two of these slices to Professor Judd some years ago, he at once confirmed my supposition that the mineral is olivine. In all these slices this mineral presents a uniform character. It is very dark, owing to the development of a fine dust of opacite along certain plains, which dust occasionally arranges itself in very fine lines; at other times magnetite has been developed to such an extent that only small eyes of olivine have here and there been left undecomposed. In some specimens a still further change has set in; namely, the magnetite, or titaniferous iron, has been removed, and a whitish, opaque substance resembling leucoxene has been left behind.

In rather thick slices the olivine is feebly, but distinctly, dichroic; and with the aid of converging polarised light, the double refraction of the mineral is seen to be positive. The olivine is in shapeless grains; and, as is usual with this mineral, though the grains are much cracked, the cracks give no clue to the crystallographic shape of the mineral. These cracks are apparently due to the strain caused by the cooling of the rock at the time of its consolidation, for the schillerization process has been extensively set up along them, the substance developed being a dusty-looking iron oxide, and not serpentine. The latter mineral would doubtless have been formed had the alteration been caused by sub-aerial agencies. Some of the iron in these olivines is certainly magnetite, for it has occasionally segregated in crystals that on being sliced have yielded square and triangular forms.

Apart from the olivine, magnetite is also abundantly developed in the rock. It is frequently surrounded by red mica, which in transmitted light, varies in colour from greenish-yellow to a rich orange-brown. The mica is powerfully dichroic, and belongs to the group that used to be referred to the hexagonal system.

Apatite is abundant in the Batteori specimens.

No. 4.—My next specimen comes from Nhára (Nara) on the south flank of the Chor—the village alluded to above. A little to the south of Nhára, the road from Chaita passes over a ridge running east and west. This ridge is capped with 50 or 60 feet of massive, white, crystalline limestone, weathering grey, which rests on thin bedded mica schists, dipping south, at an angle that varies much within a few yards. The trap is intrusive in the schists and in the limestone.

The microscopic examination of thin slices of this rock shows that it is the same as that previously described. In structure it is perfectly holocrystalline. The augite is more abundant relatively to the felspar than in the other specimens, and both the augite and the felspar are deeper in tint. Apatite, red mica, and magnetite, or ilmenite, are abundant. Olivine is present as usual, but it does not present the dark, dusty appearance of the other specimens. It has been more completely converted, however, into magnetite, or ilmenite, and the white decomposition product of the latter, though characteristic eyes of undecayed olivine, may still be seen in it here and there.

No. 5.—This specimen was collected at Serai, a village on the north-east flank of the Chor, close to the margin of the gneissose-granite. The proper name of the place is, I think, Serañ (silent n), the name of one of the local demons of the Chor, and converted, through piety or ignorance, by a Mahommadan scribe into the Serai of the map. The outcrop occurs as a dyke in thin-bedded mica schists, and is well exposed near a waterfall in a valley to the west of the village.

The very peculiar colour of the felspar, as seen in thin slices under the microscope, shows that this dolerite is the same rock as that which occurs on the south of the Chor. The felspar is disposed to be more massive than in the other specimens; but between crossed nicols it breaks up into well-twinned crystals of triclinic felspar; and, as in the other samples from the Chor, characteristic lath-shaped prisms of this mineral are imbedded in the augite.

Apatite, brown mica, and magnetite are, as usual, abundant; and some epidote is present as a secondary product. Indeed, this specimen is a good deal decomposed. The augite has been in part converted into hornblende and in part into micaceous chlorite. Similarly, the felspar has here and there been changed into a saussuritic mineral, and is invaded, more or less, by micaceous chlorite.

This slice contains no olivine; but I have only one slice, and I cannot lay my hands on the hand specimen. Of the outcrop itself, however, I have a distinct recollection; and I have not only the entry in my journal but a sketch of one portion of the dyke, showing its relation to the schists.

No. 6.—My last specimen comes from Roru, a village 24 miles, as the bird flies, from the Chor in a north-easterly direction. It is situated at the confluence of the Pabar and Sikni rivers, on the road to the Shatul and Borenda passes. The outcrop of the dolerite occurs a little south of Roru, about a quarter of a mile from Serai,[1] as a dyke in mica schists.

The felspar of this rock is all of reddish-dun colour, of exactly the same tint as the mineral of the other specimens. It is a very peculiar colour, and I think it is sufficient to identify the Roru rock as an offshoot of the Chor dolerites.

The structure is more granitic than in the other specimens; the felspar is more massed together; but under crossed nicols it all breaks up—even the more massive looking portion—into long prisms (lath-shaped crystals) of triclinic felspar. The latter mineral belongs to the labradorite-anorthite group.

Augite is abundant, and, as compared with the other specimens, it is grouped more massively. It has been, to a considerable extent, converted into secondary hornblende; and this slice affords numerous and instructive instances of the con-

[1] Not the village alluded to *ante*.

version of the one mineral into the other by processes set up after the first consolidation of the rock. Clear, colourless augite, often presenting its characteristic cross cleavage lines to view, frequently constitutes the kernel of grains, the whole of the outside being formed hornblende. At other times nearly the whole has been converted into hornblende, small patches of clear augite, with well-marked cross cleavage lines, having been left, here and there, in the midst of the hornblende.

It is interesting to note that the metamorphism of the augite is not a mere alteration in the colour of that mineral; but that it involves a complete change in its internal molecular structure and optical properties; thus the converted mineral, as may be seen in this slice, has not only acquired colour and strong dichroism; but a sensible modification has resulted in its cleavage and in the angle of extinction; the angle at which the cleavage lines intersect each other, and the angle at which extinction takes place, differing considerably in the amphibole and in the parent pyroxene that forms the kernel of the crystalline mass. In one case in which the augite is twinned, the external margin of secondary hornblende is also twinned, but the twinning plane has been shifted a little on one side, and is not in exact continuation, or in quite a straight line with the twinning plane of the augite.

Apatite is abundant, whilst ilmenite and mica (part of the latter being of red and part of clear green colour) are present as secondary minerals.

The ilmenite exhibits its characteristic rhomboidal lines; and in some cases the deposit of iron along these crystallographic lines has been so small that the section of the mineral in the thin slice appears as a mere skeleton; the external shape, however, and the internal spaces being very sharply defined. As these spaces are filled with other minerals, the effect produced is clearly not due to the cutting and grinding of the slice; the absence of leucoxene, on the other hand, is opposed to the supposition that the internal spaces are due to decay. The conclusion at which I have arrived therefore is that, in this particular case, the ilmenite is a secondary mineral, and was deposited along with the secondary mica. The secondary character of the latter mineral is clearly seen from the way in which it invades the substance of the felspar.

The felspar and the hornblende in this slice have been to a considerable extent schillerized, though it is possible that the process may have taken place prior to the conversion of the augite into hornblende. The presence of the schiller inclusions has, in every case, either interfered with the development, or the alteration set up has obliterated all trace of the characteristic hornblende cleavage. When the hornblende is clear, it is highly coloured and exhibits characteristic cleavage lines; where the schiller inclusions are abundant, there is no trace of cleavage; in the latter case, double refraction is not so strong; the colour is less marked, and under crossed nicols the polarisation is confused and indeterminate.

The most prominent of the schiller material is an oxide of iron, which when in large grains is red and translucent. It is invariably devoid of crystalline form.

I have not observed any trace of olivine in this slice; but as I have had an opportunity of examining one slice only I do not think it is desirable to lay much stress on this point. Even if a more extensive examination of the Roru outcrop failed to reveal the presence of this mineral, all that I should be disposed to infer from the fact is that it is locally absent: that the Roru rock forms a portion of the

same eruptive mass as the highly basic rock of the Chor I see no reason to doubt.

General Remarks.

The mode of occurrence of the Chor dolerite shows that it is an intrusive and not a contemporaneous eruptive rock, and the examination of thin slices under the microscope bears out the result of field observations. In structure the rock is completely holocrystalline, with a tendency towards being granitic. That is to say, it is more nearly allied to a gabbro than to a lava.

The peculiar colour of the felspar, and the extent to which the olivine is impregnated with iron, are points which may be useful in leading to the identification of the rock in neighbouring localities.

It is now ten years since I visited Batteori, and I have no recollection of the particular outcrop at that village, but I see no reason to doubt the correctness of the entry in my field journal that the outcrop is *in* what we now call the gneissose granite. The exact wording of the entry is as follows—"At Batteori a very dense heavy trap occurs in the granitoid gneiss. I traced it for some distance above the village. It finally cut down the hill side across the road in the direction of Tálichoag." The outcrops at Barela, Batteori, and Nhára, therefore would appear, roughly speaking, to be in a line with each other. Near Barela it occurs in the mica schists, near the boundary of the gneissose-granite; at Batteori it occurs in the gneissose-granite itself; it then edges away from the latter rock, and appears in mica schists at Nhára, and in the crystalline white limestones resting on them.

Corresponding outcrops also appear on the opposite side of the Chor, at Serai (near the margin of the gneissose-granite) and at Roru, distant 24 miles from the Chor. When the neighbourhood of the Chor comes to be explored it will doubtless be found in other places also.

Going hand in hand with the determination of the eruptive character of the gneissose-granite, discussed in previous papers, was the question of age, and there seemed to be good reasons for referring it to the tertiary period. If this conclusion be sound, the dolerite of the Chor would seem to be of tertiary age also, for it appears to be intrusive in the gneissose-granite at Batteori.

The occurrence of highly basic eruptive rocks of undoubtedly tertiary age in the Central Himalayas has already been noted (Records XIX, 115, and references quoted therein); and I think it probable, therefore, that the dolerite of the Chor may be referred to the period of the final building up of the Himalayas.

At many of the places noted in this paper, and at numerous others in the neighbourhood of the Chor, hornblende schists, and amphibolites, occur, which present a strong resemblance to those of the Satlej valley.

I have examined a good many thin slices of hornblende rocks from the following localities; namely, from Nhára, and Barela on the Chor (two of the localities where the dolerite occurs); from Júbal (Jabal of map) about 18 miles from the Chor in a north-north-east direction (the outcrop occurs near the top of the pass leading over into Kotkai); from between Kadara and Sungri (on the mountains that overhang the Satlej to the east, near Nirth); and form the waterparting between the Satlej and the Júbal valleys.

Under the microscope these Chor hornblende rocks and those which form con-

necting links between them and the hornblende rocks of the Satlej valley, are seen to possess common features. Hornblende is the most prominent mineral, constituting the great mass of the rock; quartz, in which a little triclinic felspar is interspersed being quite subordinate.

Garnets, generally of microscopic size, are frequently present. At Barela they are of large size, and abound both in the amphibolite and in the mica schists. Any number of them, of very perfect crystalline form, that have fallen out of the decayed schists, may be picked up on the roadside.

Red mica is very constantly present in the amphibolite and in many of the thin slices sphene abounds. When the latter mineral is not to be seen, magnetite is plentiful; but in the slices in which sphene occurs, magnetite is absent, and its place is taken by a little hæmatite.

Epidote may be seen sparsely in some of the slices.

The quartz is very pellucid, and I have only detected the presence of a few liquid cavities with moving bubbles. They were of extremely small size. Microliths of hornblende were abundant in it.

This rock has evidently been subjected to extreme metamorphism, and it is impossible to determine the character of the original rock from the microscopic examination of these amphibolites.

On the identity *of the* Olive Series *in the* east, *with the* Speckled Sandstone *in the* west, *of the* Salt Range, *in the* Punjab, *by* DR. H. WARTH.

In February last, during a short period of leave, I made a trip to the Salt Range chiefly with the view of extending the observations which gave rise last year to such interesting geological discussions, both local and general;[1] and I was so fortunate as to make a fresh find of fossils which, with other observations, must be taken to determine the identity of the Speckled Sandstone (palæozoic) with the Olive series of the eastern sections, hitherto taken to be cretaceous.

The crystalline boulder-bed in the Nilawán forms the base of Wynne's Speckled Sandstone series. It is only 1½ feet thick, but some boulders are about 2 feet in diameter. Amongst the boulders and pebbles of crystalline rock there occurs a minute proportion of pebbles consisting of soft bluish rock and some of which contain fossils, *Conularia*, *Serpulites*, etc. Such pebbles were found in the boulder bed on the left and on the right sides of the Nilawán gorge opposite the Salt mine, also to the right near the mouth of the gorge. Inside of the gorge the strata observed were the purple sandstone, then the boulder-bed, above that greenish sandstone, then very thick beds of the red sandstone (Wynne's 'Speckled') overlaid by lavender clays and more recent beds. Near the mouth of the gorge there was also seen a remnant of the Magnesian Sandstone, 10 feet below the boulder-bed, recognized by the peculiar lenticular markings described by Wynne at pages 88 and 153 in the Salt Range memoir.[2] About 50 feet lower the *Neobolus* shales were also recognized by the minute white shells which Mr. Wynne first discovered in them at other

[1] *Supra*, Vol. XIX, pp. 22, 127, 131. [2] Mem. Geol. Surv. Ind., Vol. XIV.

places (*l. c.* pages 87 and 142). The position of the boulder-bed at the base of Wynne's Speckled Sandstone is thus quite undoubted.

The fossiliferous pebbles in the boulder-bed of the Nilawán are the same as those found in the Olive Series of the eastern Salt Range. Their occurrence leaves no doubt that the boulder-bed in the Nilawán belongs to the same period as the boulder-bed of the Olive Series in the eastern Salt Range; in fact, that there is one and the same boulder-bed extending throughout the whole of the range.

It is not reasonable to imagine such a coincidence that two boulder-beds should occur in close proximity consisting of the identical crystalline rocks, in each case showing glacial action, and in one case enclosing fossiliferous pebbles, and in the other being accompanied by a regular band of fossiliferous pebbles and nodules with identical fossils, and yet that the two boulder-beds should belong to different geological periods. They must be identical, and the fact of their identity makes the whole boulder-bed palæozoic, because the Speckled sandstone underlies the Productus-limestone.

I noticed distinctly ice-polished and scratched surfaces amongst the boulders further west near Varcha. It is also quite possible that a further search amongst the thicker portions of the bed near Chidru, and other places west of Varcha, might result in the discovery of the facetted boulders known from Mount Chel and other places in the eastern Salt Range.

The identity of the boulder-bed involves that of the succeeding strata, the Olive sandstone series and the Speckled sandstone; the apparent contrast between these strata being easily reconciled. They are, as Wynne states, rather variable, but generally the following may be recognized in descending order:—

Red and purple clays. (Lavender clays.)
Red sandstones. (Speckled.)
Greenish sandstones. (Olive.)
Darker shales.
Crystalline boulder-bed. (Conglomerate.)

The greenish sandstones predominate and are more in view in the east, over the area of Wynne's Olive series, whilst the red sandstones are more strongly developed towards the west, over the area of Wynne's Speckled sandstones. Although less prominent, the red sandstone is distinctly present in the east. During the coal exploration about Dandot, several drifts were worked through these red beds. The purple clay, with its peculiarly crusted surface (*l. c.* p. 90), was also well observed at several places.

The red sandstone at Pid contains petrified wood; brown nodules 3 inches thick with calcite, barite and other crystals inside; red sandy calcareous balls, 1 inch thick, often several of them joined together; also small flat discs 2 inches in diameter weathering out, often perfectly circular (once also as a deceptive imitation of a bivalve). All these structural characteristics of the east I found repeated in the Speckled sandstone of the west at Varcha, and some of them also at Nilawán. Instead of difficulty in reconciling the different characters of these rocks, we have thus on the contrary additional evidence which would independently render the identity of the rocks extremely likely.

The correspondence of the two areas leads of course to some discrepancies with certain passages in Mr. Wynne's memoir, but they are all capable of adjustment.

On page 92, No. 8 (the Salt-pseudomorph series) is said to overlie No. 5 (the Speckled sandstone). On page 178, the Speckled sandstone No. 5 is said to be apparently succeeded by the boulder-bed No. 10, but on page 177 discordances caused by slips are spoken of in this section. On pages 104 and 154 bivalves in the Olive series are mentioned as having a cretaceous aspect.

These casual instances cannot shake the strong evidence in favour of identity. It must therefore be accepted, once for all, that the two series are one and the same, and it may be as well to name the united series for the present the *Crystalline-Boulder Series*. This name is all the more suitable because both at the eastern and the western ends of the range the crystalline boulder-bed is the only representative left of the series.

This new united series comprises the whole crystalline boulder-bed of the Salt Range from end to end, all the strata of Wynne's Speckled sandstone, and all the corresponding eastern strata which have hitherto been classed under Wynne's Olive series. This includes all the red sandstones and the highest red clays of the Olive series, probably also the last coarse white sandstone which overlies the red sandstone at several places. Above these would be separated the hæmatite clay and all the shales, sands, and calcareous beds with the coal, or the *Cardita-beaumonti* beds.

An unconformity must then exist between the Crystalline-boulder series and the *Cardita-beaumonti* beds, although the signs of it may not be very evident. Traces of the unconformity may easily be obscured amongst the plastic and crumbling materials which constitute the beds with the coal. It is obvious what the new sequence of the different series of the Salt Range must now be. The following is their order according to Wynne's table, page 69, four of Wynne's numbers being changed; the adjustment will be at once intelligible from an inspection of his diagramatic section, Plate IX.

15. Post-tertiary.
12, 13, 14. Post-nummulitic tertiaries.
11. Nummulitic limestone.
10. *Cardita-beaumonti* beds with coal.
9. Jurassic.
8. Ceratite beds. (Wynne's No. 7.)
7. Productus limestone. (Wynne's No. 6.)
6. Crystalline-boulder series. (Wynne's Nos. 5 and 10.)
5. Pseudomorphous salt crystal zone. (Wynne's No. 8.)
4. Magnesian sandstone.
3. *Neobolus* beds.
2. Purple sandstone.
1. Saline series.

Wynne's geological map of the Salt Range shows all these strata in their proper places. It must only be understood that the Crystalline-boulder series is represented by two colours; red with diagonal shading on the left and green on the right. The red comprises the area where the red and speckled sandstones predominate, the green where the Olive sandstones are more prominent. That small portion of green which overlaps the red, really represents *Cardita-beaumonti* beds.

In conclusion we may hope that in due time something may also be found amongst the Talchirs, or near them, to completely establish the truth of Dr. Waagen's more important correlations with regard to the Indian coal measures.

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FROM 1ST JANUARY TO 31ST MARCH 1887.

Soondri wood from 15 to 18 feet below surface and 4 feet above zero of tidal gauge, near Diamond Harbour Telegraph Station.

PRESENTED BY MR. S. R. ELSON.

Tooth of *Euelephas indicus* from a skull found at a depth of 24 feet in the delta of the Godavari, at Dowlaishweram.

PRESENTED BY MR. T. VANSTAVERN.

Nine fragments of pebbles with *Conularia*, from the palæozoic boulder bed in the Nilawan, Salt-Range.

PRESENTED BY DR. H. WARTH.

Five specimens of fossil plants from the Iron-stone measures, Barakar.

PRESENTED BY C. RITTER VON SCHWARZ.

Turquoise from Los Cerillos, New Mexico; and Native Antimony from Prince William York Co., New Brunswick.

PRESENTED BY MR. G. F. KUNZ.

Three specimens of jadeite and two of omphacite ?, from Upper Burma.

PRESENTED BY DR. R. ROMANIS.

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The bald record of his services, as is the custom, is thus given in the official list of officers in the Survey Department of India:—

Engaged by Dr. Oldham from the Geological Survey of Great Britain; joined appointment in India on 24th March 1854; in August 1854 appointed by Court of Directors as Professor of Geology, Roorkee College; re-attached to Geological Survey for the field season; 1854-55, Narbada Valley; 1855-56, Sub-Himalayas; 1856-57, Bundlekhand; 1857 to 1862, Sub-Himalayas; in October 1862 left Roorkee and re-joined the Geological Survey as Deputy Superintendent for Bengal; 1862-63, South Rewah; 1863-64, Behar; 1864-65, Assam; officiated as Superintendent from 21st August to 13th November 1864; leave on private affairs from 10th May to 9th November 1865; 1865-66, Central India and Rajputana; 1866-67, Chota Nagpur, Chhattisgarh, Sumbalpur; placed in the 1st grade on the introduction of grading in May 1866; 1867-68, Garo Hills; 1868-69, Hazaribagh, Sirgujah, Sohagpur, Chanda, Mohpani; 1869-70, Satpuras; 1870-71, Bundelkhand, Narbada Valley; officiated as Superintendent from 20th July to 5th September 1870; sick leave, 13th June to 2nd December 1871; 1871 to 1873, Satpuras; officiated as Superintendent from 16th July 1873 to 15th December 1874; 1873-74, Garo Hills; 1874-75, Betul coal-field, Nimar, Nepal; 1875-76, Nimar, Jamu Hills; appointed Superintendent on 1st April 1876; 1876-77, Mohpani and Satpura coal-borings; 1877-78, Reh Committee, and Nahan; 1878-79, Office, Calcutta; 1879-80, Office, Calcutta; 1880-81, Nahan, and Office, Calcutta; 1881-82-83-84, Office, Calcutta; special leave from 9th May to 8th November 1884; 1884-85, Office, Calcutta; designation changed to Director of the Geological Survey of India; 1885-86-87, Office, Calcutta; permitted to retire on 27th April 1887.

Previous to his retirement, and in acknowledging the receipt of his last Annual Report, his long and valuable services were thus acknowledged by the Government:—

" As this is the last occasion on which the Annual Report will be submitted by you, the Government of India desires to take the opportunity of placing on record its appreciation of your long and valuable services, and to recognise the zealous manner in which you have discharged the duties of Superintendence and Direction and the devotedness with which you have supported the cause of Geological Science in India. I am to add that the marked advance which has been made in the investigation of the geological conditions of India during your tenure of office is most creditable to yourself, and that it is undoubtedly leading to the development of the mineral resources of the Empire, as well as the material extension of scientific knowledge."

Notice of J. B. Mushketoff's[1] Geology of Russian Turkistan. *Compiled from translation and notes from Professor F. Tovla of Vienna, by* C. L. GRIESBACH, C.I.E., *Geological Survey of India.*[2]

The first volume of this work is arranged in two parts: the first part (pages 1—311) being devoted to a review of the results of former explorations, while the second part, from the 9th Chapter, is descriptive of the geological and orographical features of Turán and of the Aral drainage-system.

9th Chapter: From Orenburg to Samarkand. The crystalline rocks of the high steppe between Orsk and Irgis, and in the neighbourhoods of Tashkent, Khojent, and Samarkand, are discussed.

10th Chapter: Treats of the city of Samarkand; the loëss deposits and the nephrite.

11th and 12th Chapters: The western spurs of the Tian-Shán; the palæozoic island Ŭrda-Bashi, the palæozoic chain of the Kara Tásh, the cretaceous and tertiary deposits on the Sassik and Ak-Tash, the Kaspikúrt range (crystalline rocks and carboniferous limestone), and the valley of the Keless (cretaceous, tertiary, and post-tertiary) are described.

13th Chapter: This is devoted to the valley of the Fergana river (Narin-Sir-Dariyá). Jurassic-beds with coal-seams (Uch Kúrgán) are described overlaid by oil-bearing cretaceous strata (Rishtán) and gypsum and rock-salt bearing tertiary deposits. Two directions of disturbance and flexuring prevail: one from north-east to south-west (the Alai system), and a second from north-west to south-east (the Fergana system). Post-tertiary formations (conglomerates, loëss, bedded sand and drift sand) overlie the tertiary and cretaceous deposits. Permo-carboniferous (Nebraska horizon) underlie the cretaceous formation in Issfara.

14th Chapter: The western spurs of the Pamir-Alai.

15th and 16th Chapters: The Amú Dariyá valley between Chaharjui and Termez, and between Chaharjui and Petro-Alexandrovosk.

17th and 18th Chapters: The deserts of Kizilkum between the Amú and Sir-Dariyá are described.

19th Chapter: A summary of the observations contained in the preceding chapters.

Summary.

Uniformity of geological structure.

Turan presents the appearance of perfect uniformity of geological deposits in spite of the great variety of rocks which have been proved to exist; and this is mainly owing to the fact that the older formations quite disappear amidst the largely developed cretaceous, tertiary, and recent deposits.

[1] NOTE.—"Turkistan, Geological and Orographical descriptions, from observations made during journeys in the years 1874 to 1880." With a Geological Map of Turkistan, St. Petersburg, 1886 (in Russian).

[2] The present notice comes in as a fitting supplement to the several papers on Turkistan which have appeared from time to time in these Records as the preliminary result of Mr. Griesbach's late Journeying with the Afghan Boundary Commission. The paper is also of interest as referring to country which along its southern boundary just touched on the northern edge of Mr. Griesbach's work along the Khilif course of the Oxus.—(See map ante. p. 93 of first volume of the Records.)

Most of the patches of metamorphic and older formations occur in the Kizilkúm in Central Turán, which forms the watershed between the Sír-Dariyá and the Amú Dariyá or Oxus.

Structure of the eastern margin of Turán.

Beyond the metamorphic and crystalline rocks of the Múgodshár desert, the dioritic island of the Chegana river, and the palæozic limestones of the Karatan; Mushketoff again met these rocks along the eastern margin of Turán, forming small and quite isolated promontories in the Úrda-Bashi mountains, which are built up of devonian limestones and granites, while they are flanked by tertiary red conglomerates. In the Karatash range and in Badam carboniferous limestone occurs with the devonians; and the granite of the Úrda-Bashi is represented by orthoclase and felsite-porphyry with tufa. Kasikúrt is stratigraphically the most interesting island; for besides largely developed carboniferous limestone with numerous fossils, there occur igneous rocks. The isolated hill Monzar is formed of carboniferous limestone. In the Mogoltan range near Hodjénd, coarsely crystalline syenite is largely developed; also porphyritic syenite, diabase, and porphyrite. In Ferghána, Mushketoff found the Karatásh or Kashkaratá hills formed of metamorphic schists and dense diabase.

Further southwards, metamorphic rocks are found near Uratyuba and Jissuk. The Karnak range near Samarkand is formed of slate and diorite; and palæozoic limestones appear in Busgala.

Comparison with the Tian-Shán.

When comparing these rocks with those of the Tian-Shán, a great difference between them becomes at once apparent.

The former are much more metamorphosed than the latter. For instance, the minor range of Sultanis-Dagh shows a remarkable diversity of slates, often highly metamorphosed and with many mineral veins; whereas in the Tian-Shán such rocks can only be observed at great intervals and at very few localities. In the Sultanis-Dagh occur rocks, which are entirely wanting in the Tian-Shán, as for instance typical talcose and pistacite slate and eklogite. In the former range, the granites, diorites, and porphyrites show unmistakable traces of metamorphism; whereas in the Tian-Shán this is never the case. The granites too are more closely allied to the Ural granites than to that of the Tian-Shán. Veins of coarsely crystalline granite, containing fine crystals of almandine, beryl, and red schorl, are common in the former area, but quite unknown in the Tian-Shán; on the other hand, the Ural, as for instance, near Múrsinka in the Hinen range, has been long celebrated for its precious stones.

Western margin of Turán.

Similar metamorphic and palæozoic rocks are met with along the western borders of Turán. According to the researches of Messrs. Felkner, von Koshkul, G. Sieners, E. Tietze, and others, crystalline rocks, chiefly granite with porphyrite veins, are developed in the Kure and Kuremin-Dagh hills near Krasnovodsk, which may be looked upon as a continuation of the Balkhán range.

Useful minerals in Turán.

A few unimportant localities of useful minerals are found within the crystalline and metamorphic areas. Besides almandine and beryl, traces of gold and copper ores are found in the granites of the Sultanis-Dagh In the syenites of Mogoltán, some

argentiferous galena occurs, accompanied by green fluorspar. Traces of copper ores are found in the clay-slate of the Ura-Júke. According to Pander, gold and turquoises are found in the granite and porphyrite of the Bukantán hills.

The sedimentary strata of Turkistán. Plant-series.

Mesozoic strata containing land-plants rest on the palæozoic and metamorphic rocks. According to D. Romanofsky, many of the plants found in the mesozoic series of Turkistán are identical with jurassic, others with rhætic, and some even with triassic species. The entire mesozoic series however is of fresh water origin, marine forms being absolutely wanting. Romanofsky believes that Turán formed part of a continent from early triassic to cretaceous times, which extended a considerable distance eastwards. Neumayr looks upon it as the Turánian island in a jurassic ocean.

Jurassic deposits are only met with at very few localities in Turán; but they are of great practical importance since they contain coal-seams. Coal-basins of importance have so far only been found along the borders of Turán, in the valleys of the rivers Bodam, Seiram, and in Ferghána. In the latter area they are well developed. Others may possibly also be found along the western borders; at present they have only been shown to exist in Mangishlak. The jurassic deposits rest invariably discordant on the palæozoic rocks; whereas the cretaceous strata and tertiaries are usually conformable to them. Only locally is there an unconformity visible between the jurassic and the overlying cretaceous formations.

Cretaceous and tertiaries.

The cretaceous and tertiary deposits are the principal rocks of Turán where they reach an enormous thickness; altogether about 2,000 feet in Ferghána and 5,000 in Hissara. They are always closely connected and are conformable to each other. The stratigraphical features are most complicated in the hill-ranges, especially in Keless and in Ferghána; but the further away from the hills of Eastern Turán, the simpler becomes the structure until, in Central Turán, the strata are perfectly horizontal; an exception forms the Sultanis-Dagh and Bukantan (in Kizilkum), where a north-west strike prevails.

The lithological character of the cretaceous deposits varies considerably. Where they are well developed, they consist of a great thickness of bright-coloured beds of gypsum, clay, marls, and shell-limestone, with micaceous and ferrugenous sandstone. The sandstone, limestone, and marls are remarkable for their regular development, whereas the clay-beds and gypsum deposits often thin out at short distances. The first group of rocks is found all over Turán, the other only in the Tian-Shán, Pamir, and Alai; in Ferghána, for instance, the complete series of rocks is found; whereas only the first group of beds occurs near Kilef on the Oxus.

Away from the eastern hill ranges the lithological character of the rocks becomes modified—the shell limestone passing into oolitic and dense limestones, and the bright coloured (red and green) micaceous sandstones becoming more uniformly light grey and yellowish coloured. The fossils are mostly so badly preserved that a division of the Turánian cretaceous group into horizons is hardly possible. Romanofsky divides the cretaceous group into two horizons, namely, an upper or Ferghána formation, containing numerous species of ostrea (near the Oxus mouth some Ammonites of senonian types also occur), and a lower horizon characterized by some ostrea, rudistes, echinderms and a few brachiopods. In Ferghána, the creta-

ceous formation yields naphta, especially at points where there is a change in the strike of the beds. According to Konshin, the naphta and ozokerite of the Western Turán belong to a younger geological horizon than the Ferghána deposits.

Tertiaries.

The tertiary deposits are closely connected with the cretaceous group in central Turán; they are unfossiliferous in the spurs of the Tian-Shán, casts alone occurring and then only in a very few beds.

Nummulitic limestones occur on the Aral, but are not found elsewhere in Turkistán. They are overlaid by lower and middle oligocene fossiliferous deposits (sandstones, clays, and limestone), followed by miocene limestone and sarmatic clays.

The tertiary series of the Tian-Shán is poor in fossils and can scarcely be divided into separate horizons. Romanofsky believes that eocene, oligocene, and miocene formations are represented, overlaid by a largely developed pliocene formation.

As eocene, he considers strata with *Sphenia rostrata*, Lam., *Modiola subcarinata*, Lam., *Modiola jeremejewi*, Rom., and *Avicula trigonata*, Lam. From the oligocene he cites: *Alligator darwini*, Ludw., *Ostrea raincurti*, Desh., *Ostrea longirostris*, Lam., &c.

The miocene and pliocene chiefly consist of conglomerates and sandstone beds, and are closely connected with the younger Aralo-Caspian formations. A characteristic *Valvata* is found in the largely developed pliocene deposits.

It was observed that the tertiary formations also change in lithological character further away from the hills; the shell-limestones disappearing and being replaced by sandstones. The green gypsum and rocksalt-bearing clays which are so largely developed in the east gradually thin out westwards, and the great salt deposits disappear altogether. The coarse conglomerates pass into fine-grained varieties.

According to Mushketoff, it appears that the tertiaries of the Tian-Shán have been deposited near a coast line; whereas those of the Aral neighbourhood are of purely pelagic nature. He believes that the nummulitic sea had a considerable depth which gradually decreased in the following periods: for instance, the Ust-Urt became dry land during the sarmatic epoch, whereas the lower Sir-Dariyá and Oxus regions remained a marine area till pliocene times.

The pliocene marine area was the forerunner of the present Aralo-Caspian basin, which gradually broke up into several smaller and isolated lake-basins, many of which exist to the present day, although constantly lessening in size and depth.

The entire series of formations, from the cretaceous to the younger tertiaries, forms one connected whole in which the boundaries between the several groups are exceedingly obscure, owing to the gradual changes which took place during the deposition of the series. During the whole period of time, from the cretaceous to the pliocene, Turán was covered by a sea, which spreading over the jurassic continent existed at first as an open ocean. This gradually changed to a mediterranean sea; and after deposition of the sarmatic detritus, it became a completely land-locked basin, which steadily lessened in extent until it is now represented by several isolated lake areas.

The stratigraphical features prove that contemporary with this change in the extent of the ocean area, an uninterrupted process of folding took place in tke surrounding land area; the outlines of the present hill ranges having begun to form before the deposition of the cretaceous formations.

The Aralo-Caspian deposits are of very varying thickness. Generally they are yellow or greyish-blue sandy clays with fine, often false bedding, completely corresponding lithologically with the upper deposits of the Kalmück desert. The brown and dark blue clays and white quartz sandstones of the Caspian deposits are entirely wanting in Turán.

The fauna of the Aralo-Caspian formations agrees with the living fauna of the Aral and Caspian seas. *Cardium edule*, L., *Dreyssena polymorpha*, Van Ben., *Neritina liturata*, Eichw., *Adacana vitrea*, Eichw., *Hydrobia stagnalis*, L., *Anodonta ponderosa*, Pfr., and a sponge, *Metshnikowia tuberculata*, Grimm, were found in Karakum, north-east of the Aral. These are forms, which in the Caspian live close in shore, in depths at most of 8 fathoms: *Cardium edule* being alone found at greater depths. *Hydrobia stagnalis*, *Metshnikowia tuberculata*, and *Anodonta ponderosa* live at still lesser depths. Nearer the Aral was found *Lithoglyphus caspius*, a species which occurs in the Caspian at the present day at depths varying from 7 to 108 fathoms. The Aralo-Caspian deposits in Turán are to be considered therefore as shallow-water formations.

Grimm has shown that the distribution of the living fauna of the Caspian is closely connected with the existence of great deposits of drift-sand. Where the coast-line is influenced by waves of drift-sand, he found animal life almost entirely wanting, a fact which, as Mushketoff believes, explains the sporadic occurrence of fossil remains in the Aralo-Caspian deposits.

The boundaries of these deposits can only be observed here and there. According to Mushketoff (contrary to the opinion of Barbot de Marni), the Ergeni hills west of the Caspian formed the old shores, and near the parallel of Manytsh a narrow channel formed a connection with the Pontus. Ust-Urt and the Mugojár range partly interrupted the connection, forming a long and narrow promontory in the Aralo-Caspian sea, and thus divided it into two separate basins. Sewerzoff thinks that the eastern basin may have reached as far as the Balkash lake; whilst to the southward the parallel of the Sultanis-Dagh may have partly formed the boundary.

The western and larger "Caspian" basin was the deeper. The channel which connected both runs between the two Bálkhan ranges; therefore along the Usboij to eastwards, into the so-called Sarykamish basin which was again connected with the Aral-basin through the strait of Aybugir between the Ust-Urt and Sultanis-Dagh.

Mushketoff expresses himself decidedly against Grimm's opinion that the Usboij was the former course of the Oxus.

Climatic changes brought about, and are still active in bringing about, the narrowing of both sea tracts of the Aralo-Caspian area; the disappearance of the channels of communication between both basins having been the first step in the direction of this shrinkage.

Mushketoff divides the drift-sand into two kinds, which form the littoral and the continental areal deposits.

*

Dry and cold north and north-east winds are the prevailing air currents during the dry seasons (summer and autumn); they absorb moisture, even such moisture as the soil may receive from rain and snow during the remainder of the year. This accounts for the rapid destruction of the cretaceous and tertiary sandstone, the decomposed material of which is carried away by the air currents of the dry seasons and re-deposited in the deserts of the Oxus and Sir-Dariyá.

Crystalline *and* Metamorphic Rocks *of the* Lower Himalaya, Garhwal, and Kumaun. Section I, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India* (with map and plate).

INTRODUCTION.

Although much has been done recently, by Colonel McMahon, to bring to light the structures of the gneissose and other crystalline rocks of the N. W. Himalaya, and to frame reasonable hypotheses as to their cause, it must be admitted by every one who has looked into the subject that much yet remains unaccomplished. Microscopical work of high order, and detailed sections carried along one or two lines of country, are of the greatest service to geology; and the value of the papers which Colonel McMahon has from time to time contributed to this journal cannot be over-estimated. But for the rational account of an expanse of crystalline rocks something more is wanted which the above cannot supply; I refer to the actual tracing, step by step, of their relations in the field, or in other words, a patient mapping of the district on an adequate scale. Petrography at the present day is in such a state of transition with regard to many of its most vital principles, that the reading of any one district by the petrographical alphabet made out in another should be supplemented by deliberate endeavour to ascertain how far that alphabet can apply to the district, and by how much it falls short. With this end in view, it seems to me that fairly detailed descriptions of the arrangement, internal structure, lie, and associations of the crytalline rocks of this part of the Himalaya, drawn from exhaustive field observations, will constitute the safest and most impartial evidence attainable in the great questions always pressing for solution among crystalline and metamorphic rocks. I therefore propose to describe here and subsequently a series of localities where these rocks appear to show to the best advantage, the descriptions in

all cases being based on a thorough mapping of the area on the one inch scale. There will then be no need for elaborate argument and careful balancing of probabilities; each locality will tell its own tale, so far as structure, lie, and behaviour of the rocks can tell it; each district will depend entirely on its own internal evidence alone, and I shall endeavour as much as possible to banish the risky proceeding of generalizing over large areas. Detailed field exploration is the basis of geology, and sooner or later will extract the secrets from the rocks; and that without recourse to interpretations borrowed from other countries, which may be, but are equally likely *not* to be, applicable, and without appeal to principles and theories supposed to be universally accepted, but which may be after all only partially true.

DUDATOLI MOUNTAIN, BRITISH GARHWAL.

I will begin these descriptive notes by an account of Dudatoli Mountain and its surrounding spurs. I have already mentioned it in a previous number of the "Records," but without giving any details.[1] This mountain, which rises to the height of 10,188 feet, constitutes the source of the Ramganga and the east and west Nyar rivers, all of which are tributaries of the Ganges. It is by far the highest mountain in the neighbourhood. Most of its upper slopes are covered with dense forest of pine, with an undergrowth of Ringall reeds; snow lying for a great part of the year among its sheltered and rocky fastnesses. Without implying more than is directly stated, I may say that it bears a very strong resemblance to Kalogarhi Mountain[1] (Kálandanda) situated further to the south-west and near the plains and also to the Chor Mountain near Simla; both in the way it rises above the surrounding country and in its geological structure.

Geological structure.

Speaking roughly, Dudatoli and its neighbouring hill spurs may be said to be composed of two sets of rocks, namely, mica schist and gneissose granite. These vary among themselves and shade off into different varieties which will be mentioned in due course. Their general surface arrangement will be seen from the accompanying map. The structural features are those of a quaquaversal synclinal elongated in the direction north-west—south-east. The uppermost and lowermost beds are schists of varying character; whilst the gneissose granite appears at numerous horizons insinuated among the schists, seemingly bedded with them, but in lenticular beds which expand or thin out with extreme rapidity. On the east, south, and west sides these lenticular beds are very prominently developed, whilst on the north there is only one thin but continuous band. The Dudatoli ridge itself is very nearly uniformly composed of the gneissose granite, the one or two thin bands of mica-schist which intervene being very unimportant. East of a line between the two Dudatoli peaks, the gneissose rock rapidly breaks up into a fringe of thin beds whose foliation planes dip roughly towards the south-west. They ultimately thin out altogether. West of the two peaks there is one blunted protruding mass in the direction of Gulek, whilst the long thin band alluded to above passes from Dobri trigonometrical station by Tarakakand, Banjkot, and Kotkhandia trigonometrical stations, and the villages Sountee and Hartur. Near the last mentioned place it is interrupted by a fault, but apparently was originally continuous into re-connection with the Dudatoli massif by means of the band

[1] Records, XX. pt. 1, p. 40.

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which now runs along the Bandh[illegible] ridge. This tongue of gneissose granite has thus almost completed an ellipse of outcrop, and from the quaquaversal dip can only indicate a continuous sheet beneath the schistose strata of Naori which are the highest beds visible of the series. Apparently below this continuous bed there are several more lenticular masses of the gneissose granite inserted between the schistose strata, but only outcropping on the south side of the synclinal. They rapidly thin out towards the north-west beyond Dujukatoli and gradually coalesce for the most part towards the east-south-east and join the south extension of the Dudatoli massif. South of Kainur there are one or two very thin beds which run for a short distance and thin out both ways. If they have any connection with the main mass of the rock it must be a subterranean one.

I have already called attention to the like disposition of the similar rocks at Kalogarhi Mountain and at the Rama Serai,[1] and I here lay especial stress upon the fact, because in a line of section from the Sub-Himalayan boundary to the snows running through Kalogarhi, Dudatoli, and Kedarnath, the only regular apparent synclinals of any importance are connected with the gneissose and schistose series. Nowhere except on the north side of a mass of gneissose granite is there ever a prevailing south dip of the strata. This may be either a coincidence or a necessary relation. I leave the question at present to be afterwards returned to.

Schistose series.

I now come to some of the most marked features in the schistose series, which forms as it were a groundwork for the gneissose granite. Over a large area these rocks consist of the more arenaceous, or quartz-schist type with thinner dividing beds of more argillaceous schists; the schistosity being not very marked. Foliation takes place in the majority of cases along the original bedding, as is well demonstrated, where the arenaceous and slaty types interbed. In some few cases however I found it crossing the bedding along incipient cleavage planes, especially in some quartz-schists; whilst films of mica were often visible along joint planes. In addition, wherever the rocks had been much crushed and cut by nearly parallel divisional planes and by slickensides their surfaces were also coated with a thin micaceous glaze. In some cases among the quartz-schists laminæ more or less micaceous had been cleaved across, and the mica plates re-arranged perpendicular to the laminæ where they occur. To whatever cause this regional metamorphism be due, it is certain that it begins imperceptibly and continues with a minor degree of intensity over a large tract. The section from Shánkar on the Ramganga due north to near Hansuri on the east Nyar plainly demonstrates this. About a mile from any outcrop of gneissose granite as we approach the Dudatoli massif, in no matter what direction, there is a rapid, but gradual change sets in in the metamorphism of the schistose beds. The faint films of micaceous material assume by degrees the aspect of distinct layers of mica plates of considerable thickness. Vein quartz appears ramifying along the foliation planes. Garnets gradually assemble in the schist; first showing as minute pin-heads under a coating of what one may call mica-leaf, and gradually increasing in size and definiteness concomitantly with the mica until they reach an average size of peas, and rarely as large as filberts. On every side of the Dudatoli area can these most

[1] Records, XX., pt. 1, p. 30.

striking changes be observed. In the present paper I am only offering evidence collected in the field, and consequently confine my observations to what is visible under a pocket lens or to the eye.

Varieties of the schists.

The more intensely crystalline schists may, as a rule, be divided into two kinds from a structural point of view. The more common type is one in which the planes of foliation have a wavy or blistered appearance, and are completely covered with mica of a pale silvery hue. The leaves of mica are, as it were, welded together along the wavy irregularities of the foliation planes, forming an uninterrupted layer of the shining mineral. Under the lens the garnets are of a dull claret colour, and when not mere grains are of a more or less distinctly crystalline form. The break of continuity along the foliæ, caused by a garnet, is always overcome by the mica plates waving round it on both sides. Nevertheless, I also found other plates which ran undisturbed towards the garnet, and then stopped abruptly (see fig. 1). The quartz, which in this type is very subordinate, is of necessity present in lenticular layers between the waving sheets of mica. Secondary quartz, in large lenticular or nodular strings, enwrapped in a thin tissue of mica, is frequently met with. The other type of schist is a much more quartzose rock, and is regularly bedded with the former. The mica in this case does not cover in, in a complete manner, the foliation planes. Instead, it is disseminated in small flakes, and is of silvery hue, and also brown. At the same time, their arrangement is always parallel with the bedding, causing a genuine foliation. Garnets are scarcer than in the former rock.

The first of these two types is only rarely puckered or corrugated. Near Malkori pass south-east of Dudatoli there is a variety in which the mica plates, with a leaden sheen, have the appearance of shrivelled tea-leaves. A rather singular structure arrested my attention in the schistose beds as they are advancing from the widely spread slightly schistose kind to the more intensely metamorphic border round the gneissose granite. The foliation surfaces, which were very regular, straight planes, shewed a set of parallel ridges and furrows running in the direction of the dip. They were very minute, and a good idea of the effect to the eye may be obtained from the aspect of a corrugated iron roof.

I may here emphasize two points—first, the schist found near the gneissose granite is entirely a thorough crystalline schist, a fact needing no microscope to demonstrate; and secondly, along a line of country, where rock is exposed at every step, it is seen that this culminating intense form *graduates* into a wide-spread less intense form, and that in turn *graduates* into ordinary slates and quartzites.

From the universality of the changes as the gneissose granite is approached, it is only reasonable to conclude either that the extra schistosity and the development of garnets were brought about by the introduction of the gneissose granite (in whatever way the latter was produced), or that they and the gneissose granite were the joint result of some more remote and subtle cause. In any case, the two rock slates are so inseparable that they may be classed as contemporary. It follows that whatever can be proved concerning the geological age of the one may be taken as evidence for the age of the other. The importance of this will be noticed in a paper to follow.

I was unable to gather any clue from the manner of occurrence of the garnets.

The bending round of the mica plates does not satisfy me as an argument for the priority of crystallisation of the garnets.[1] I may, however, say that the latter in all their stages, from the minutest speck to the fully crystallised form, were always intact: there was no sign of crushing or drawing out of them with the foliation. Perhaps a microscopic examination may yield more decisive results.

Gneissose granite.

Turning now to the gneissose granite of the Dudatoli neighbourhood, it is necessary to say something of its mineralogical composition. In this I shall be brief, partly because the rock seems to answer perfectly to much of the allied rock already so luminously described by Colonel McMahon, and partly because the object of this paper is rather to draw attention to the larger aspect of the rock in the field than to its microscopical character. At the same time, I may point out that its coarsely crystalline condition makes the examination under the lens not so hazardous and superficial a matter as it might otherwise appear. It must be borne in mind that I am speaking at present of the rock in this locality of Dudatoli only.

The rock as a whole may be said to be eminently felspathic, and distinguished from an ordinary granite or gneiss by the presence of schorl crystals. These latter occur in all manner of conditions, from large to small, from perfect prisms to others which are manifestly severed portions of a single prism, and held together like a string of beads. The schorl is the most completely crystallised of the minerals; the micas, black and white, come next, often constituting the only perfectly crystallised minerals in the rock. Orthoclase, in rectangular prisms sometimes twinned, is not typical in the rock, but usually appears as in an "augen" or kernel gneiss. The quartz as in all granites is always without crystalline form and fills the interstices between the other minerals. In many cases minute granules of quartz and small portions of schorl are contained in the larger porphyritic orthoclase crystals and "eyes." Garnets occur very sparingly, sometimes singly and sometimes in nests. Kyanite, Beryl, and other accessory minerals I am confident are not present in this locality.

This outline is sufficient to shew the general mineralogical resemblance between this rock and others described by numerous writers on other parts of the Himalaya.

In themselves the minerals are not so important as in their mode of arrangement which varies so conspicuously in different parts of the same mass of gneissose granite that it requires very special mention. In describing these I may add that they are paralleled nearly always in the Chor and Kalogarhi Mountains; but at Kedarnath we come upon rocks of an altogether different structure, and none of the remarks to follow will consequently apply to the gneissose rock of the snowy range where I have at present seen it. The latter better agrees with Stoliczka's "Central gneiss"[2] or what Fouqué and Lévy call "gneiss granulitique."[3] I hope to describe it later.

Varieties of the gneissose granite.

The Dudatoli gneissose granite for the purpose of classification easily divides up into three types—(A) FOLIATED, (B) SEMI-FOLIATED, (C) NON-FOLIATED. These three all graduate one into the other.

(A) may be sub-divided into (1) *Tabular foliated*, (2) *Lenticular-Tabular foliated*.

[1] See Minéralogie Micrographique, Fouqué and Lévy, Manche III., fig. 2.

[2] See Mem. G. S. I., V., pt. I, p. 12.

[3] Minéralogie Micrographique, p. 175.

(A) (1) is a variety not often seen in this part, and then only near the junction with the schists. It is the most decidedly fissile of any of the varieties, It is built up of continuous straight foliæ of felspar and quartz, with intermediate foliæ of mica in continuous films. These each run their own course at least for a great distance without coinciding, the mica being very generally muscovite only. To the weather and to the hammer this rock behaves more like a schist than a granite (see fig. 2).

(A) (2) is much more common, especially in the thinner bands of the rock, which occur near the outskirts of the gneissose granite area. In it the felspar is still undifferentiated into eyes or crystals; but the foliæ of felspar and quartz swell out and thin again (see fig. 3), foreshadowing the perfect eyes of the prevailing forms of the gneissose granite (see B). In using the words "undifferentiated" and "foreshadowing," I by no means imply that the lenticular-tabular is necessarily an embryonic condition of the augen. It seems as likely that the reverse is the case, for in some quartzites of coarse grain, between Rudarprayag and Agastmundi, I have seen the grains, originally rounded, absorbing smaller portions of quartz at each end and so taking on a lenticular appearance, which with the mica films developed coincidently gave the appearance of a lenticular-tabular quartz schist (see fig. 5).

(B) may be sub-divided into (1) *Augen*, (2) *Porphyritic-augen.*

In (B) (1) the different mineral layers are no longer distinct. On the contrary, the mica plates of two layers unite with each other on each side of an "eye," thus cutting up the felspathic layer into a number of isolated eyes (see fig. 4). The long axes of the eyes being parallel give the semi-foliated character to the rock. Connected with this sub-division is a rock, which on the foliation planes shews eyes of felspar blotched and drawn out in the direction of dip. It and the lenticular-tabular quartz schist mentioned above seem to indicate differential movements of the particles of the rock, and are paralleled by structures in other basic rocks, which I hope to describe in another number.

(B) (2) only differs from (B) (1), by containing, in addition, larger, more blunted eyes at intervals, very often turned in directions other than parallel with the foliation and sometimes approximating to a rectangular outline. This sub-division is the most developed of any at Dudatoti, the Chor and Kalogarhi.

(C) in all respects resembles a normal granite, and is usually porphyritic, the porphyritic crystals being always sharply rectangular and often twinned. They are oriented in all directions.

General facts of distribution.

The result of a careful examination of the Dudatoli area is to shew that the sub-division (A) (2) is nearly always found in the thinner bands of the rock, and in the thicker ones near the junction with the schists. The division B is found impartially in all but the thinnest bands. The division C is only found in those parts where the bands of gneissose granite have united together to form a wide continuous mass, and then only in small quantities compared with the division B. These results may be shortly stated by saying that the more the rock loses its bedded appearance the more it approaches a massive and perfectly granitic form; whilst wherever it alternates rapidly by interbedding with the schists, the foliated and semi-foliated types predominate.

I must now advert to a consideration of the inter-relations between the schists and the gneissose granite. These are of such great importance in understanding by how much the latter has acted functionally as an intrusive rock, are so amply demonstrated by close work with the hammer, and may hence be said to be the field-geologist's speciality, that I make no apology for treating them fully in this place.

Inter-relations between the schists and the gneissose granite.

The gneissose granite of Dudatoli, in no case that I know of, breaks through the schists, disturbing them: no violent contortions, no puckerings of the foliation planes ever take place as distinct results of the intrusion of the gneissose granite. The difference between this rock and a genuine intrusive granite with large masses of muscovite, which very rarely occurs in the Dudatoli area, and which by the fact that it has no passage forms towards the gneissose granite may be considered to be entirely distinct and doubtless of another geological age, is most marked. A block of mica-schist containing the latter is penetrated irregularly by an amœbiform mass of it which at every thrown-out process or vein has crumpled and tortured the schist into utter compliance with its own irregularities of shape. Compare this with the thin band of gneissose granite near Hansuri, thoroughly exposed in the river section. Its upper and lower surfaces are perfect planes fitting in with similar planes in the mica schist. If the former rock had been sawn in a mason's yard and fitted in with artistic precision, it could not present a more composed aspect, both in its own regular structural planes and in those of the mica schist among which it lies. And yet the two rocks are so unlike that a pencil point may be placed precisely on the junction line. Or consider again what looks on the map a contradiction to the statement of its non-eruptive character, *viz*., the blunted process near Gulek. At Burari the dip of the foliation of the gneissose granite is S.-W. 30°; and that of the schists in contact is perfectly parallel. Following the junction boundary north-west, there is, near Risti, a more westerly dip in the gneissose granite; and this is also conformed to by the schistose beds. East of Gulek the dips of both have worked round towards the north-west, still retaining their concordancy. Similarly, if the boundary line be further examined, turning towards the north and north-west below Dobri trigonometrical station, it will equally be seen that there is no sudden intrusion, no erupting of the one rock among the other, but on the other hand that each has its foliation planes perfectly parallel with the other, and there is no contortion or puckering of the mica-schist whatever. Without going into detail over the whole map, I may summarily state that everywhere, except where a fault is manifest, the lie of the one rock coincides completely with the lie of the other: such an event as the foliation lines of one crossing at right angles the foliation of the other is unknown.

That the foliation represents true bedding, is placed beyond a doubt by the numerous river sections where from a great height the interbedding of the two rocks can be traced conforming to the trend of the foliation planes. Thus the gneissose granite is *insinuated* among the schists; and if it is intrusive from a foreign source, and not inborn, it must have acted on the principle of the wedge and parted the schists with wonderful precision along very great distances. At Kalogarhi the same remarks apply.

Junction exposures.

The individual beds of the gneissose granite are, as a rule, sharply marked off from the mica-schist, although a large bed nearly always splits up into numerous smaller ones near the schistose margin. These cannot be rendered on the map. An exception to this rule at Eera village is very striking. There the schists merge into the gneissose granite by the gradual acquisition of felspar. This takes place in such minute quantities at first, in the form of small veins, that it is impossible to say where the one rock ends and the other begins. The same conditions are repeated numberless times; so that only diagramatic mapping can be attempted there.

The junction section at Marwara needs a few special remarks. The gneissose granite of (B) (2) type does not fade away into the schist, but it stops abruptly and is followed by a pure mica-schist composed of bronze-coloured mica and quartz. But among the mica-schist next the gneissose granite there are thin beds, 3 or 4 inches across, of fine-grained gneissose granite, very sharply cut oft from the mica-schist. There may be a dozen or more of them (see fig. 6). Notwithstanding their thinness, porphyritic crystals of orthoclose are developed, often filling up the whole of the breadth of the band, and even where too large slightly bulging out the walls of mica-schist.

One more junction structure, well marked at Byansi, is that of a mica-schist as a ground-work, in which large porphyritic eyes of orthoclase are developed singly or in strings. The schist is fine-grained and the eyes of orthoclase stand out in bold relief. In other parts of the Himalaya I have seen this doubtful form prevailing almost to the exclusion of any other.

Inclusion in the gneissose granite.

I have only seen one included fragment of rock in the Dudatolī gneissose granite. This was in a large torrent boulder in the stream below Kainur. The boulder was of the porphyritic augen type, and the included fragment of mica-schist of the more arenaceous kind (see fig. 7). Doubtless more exist, but I am inclined to think they are by no means plentiful. A cursory examination of the Chor in 1884 revealed several examples of inclusions of schist and quartzite; whereas more detailed work at Dudatoli has only been rewarded by one find.

Geotectonic features.

Returning to the geotectonic features of the area, the problems expressed in the present synclinal arrangement of the beds are many. The certainty that at some period there must have been a folding of the rocks leading up to the synclinal, provokes the question whether this earth-movement took place before or after the introduction of the gneissose granite. If before, then we have to account for the latter choosing a widespread synclinal oasis as the place at which to escape from its plutonic confinement; if after, we must seek for the influence, which the gneissose granite possessed, in holding in check the waves of flexure, which setting in from all sides seem to have subsided so conspicuously before the gneissose granite, here, at Kalogarhi and at the Rama Serai. One other alternative, that they were contemporaneous, remains. Can the waves of contortion, meeting at this point, have neutralized one another's sensible movements and thereby induced the movements of particles and of molecules, causing cleavage, heat, and metamorphism?

In endeavouring to look these questions in the face we have the following facts to go upon:—

(1) Plutonic and metamorphic action by their deep-seated nature cannot be said to be influencing the Dudatoli area at the present time, nor to have done so in the immediate past.

(2) A wave of contortion of the strata, resulting in a quaquaversal thrust plane round the Kalogarhi centre, in post-nummulitic times, was proved in my last paper (Rec., XX, pt. I); whilst successive waves of longitudinal flexure, at still more recent dates, involving last of all the Siwaliks, have long been acknowledged as affecting the whole of the Himalaya.

From these considerations it seems that the crystalline rocks of Dudatoli must have long ago finished their metamorphism, whilst they have continued to suffer tangential pressure all through tertiary and recent times, if not from a more remote period. I am aware that Colonel McMahon holds to the late tertiary age of the gneissose granite of other parts of the Himalaya; but speaking of the parts of Garhwal and Kumaun with which I am acquainted, I fail to see how a rock of *deep-seated origin*, like that of Kalogarhi at a present elevation of 6,000 feet, can by any possibility be later than tertiary strata *in the same locality*, prominent for nothing so much as their uniform restriction in height to between the 3,000 and 4,000 feet levels. (See map, Rec., XX., pt. I.) And further, from their forming that prominent feature on the plain-ward side of the hills, to which the name Sub-Himalayan has been given, out of which they stray markedly neither in an upward, downward, nor lateral direction, it would be unreasonable to urge that they might have once covered much of the Himalayan region, and that their present state is but an infinitessimal relic of their former wide extension, dropped or forced low by faulting. That reversed faulting has in a manner tended to preserve them when they would otherwise have perished much more by denudation I have no doubt; but looking at the tertiaries in a broad comprehensive light, it is manifest that their position on the plain-ward edge of the hills at a uniform height and extending for hundreds of miles thus, is analogous on a large scale to a raised beach or high level gravel only *modified* by subsequent faulting. This is in substance what Mr. Medlicott has always advocated.[1] Pushing home the argument still further there is a step-like arrangement among the individual members of the tertiaries; for the oldest is usually in the highest position and reaches further into the Himalaya, whilst succeeding younger members stand at lower levels and nearer the plains, the last of which the Siwalik fronts the plains and rises out of them to a comparatively low elevation. Hence it is clear that each lateral thrust of the mountain area since nummulitic times caused, or was accompanied by, a further rising of the margin of the hills; and the tertiary deposits were stranded, one after the other, in positions varying in height according to their age.

To urge that the gneissose granite of Kalogarhi, at 6,000 feet, could have been formed during this tertiary period of steady periodical rise, is akin to claiming a sea-cliff as younger than the sandy shore at its base. There is also good reason to think that if the country had been depressed in tertiary times sufficient to allow of the

[1] Mem. G. S. I., III., pt. 2, chap. III.

Fig 1

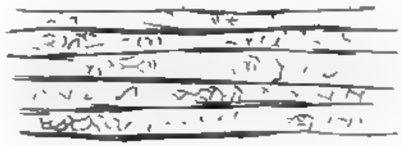


Fig 2.

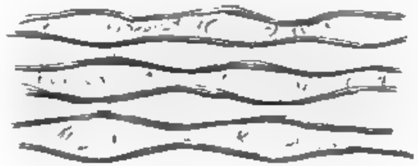


Fig 3.

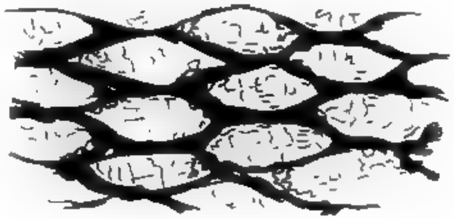


Fig. 4

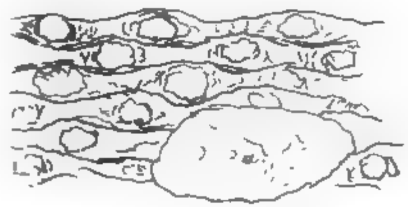
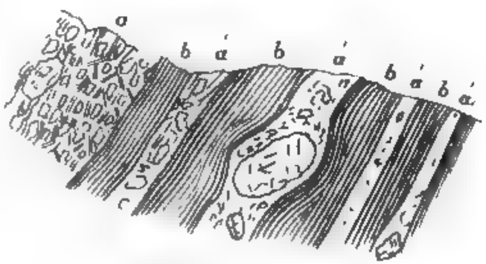
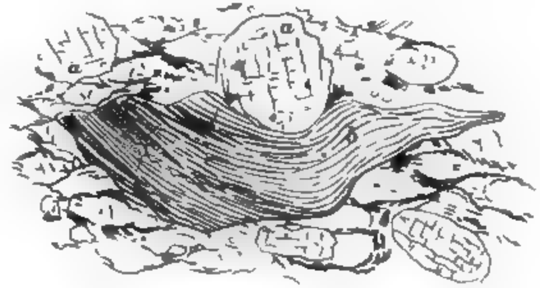


Fig. 5.





formation of the gneissose granite where Kalogarhi now is, there would have been some phenomena of metamorphism exhibited by the tertiaries themselves, especially since in the Kotedwar glen they are only distant 5 or 6 miles from the intrusive boss of Kolagarhi.

On the whole, it would seem that Plutonic action first, followed by mechanical strain due to tangential pressure as the Himalaya continued and continue growing, must be considered the order in which the agents of change have acted on the Kalogarhi and Dudatoli areas. That this lateral pressure acting on slates and schists should bend them to its will, is not surprising; but we can also imagine that wherever they were stayed by ribs of massive granite, they would have strength to resist largely the contorting pressure, which would then spend itself producing re-arrangements of the particles and of the crystalline texture of the rocks, thus imprinting on them a foliated or semi-foliated character.

REFERENCES TO PLATE.

Fig. 1. Garnet in schist, shewing mica films folding round it.
" 2. Gneissose granite, FOLIATED: *tabular*.
" 3. Ditto ditto *lenticular-tabular*.
" 4. Ditto SEMI-FOLIATED: "*augen*."
" 5. Quartz schist shewing lenticular-tabular foliation a=pebble.
" 6. Section at Marwara, near Kainur: a=gneissose granite mass. a'=thin bands of gneissose granite b=mica-schist.
" 7. Inclusion of mica-schist (b) in gneissose granite (porphyritic "augen" near Kainur. a=porphyritic orthoclase crystal.

Preliminary Sketch of the Geology *of* Simla *and* Jutogh,[1] *by* R. D. OLDHAM, A.R.S.M., *Deputy Superintendent, Geological Survey of India.* (With a map.)

The geological structure of the Simla hill station, if regarded in detail, is one of extreme complexity of varying dips and innumerable faults, but on the large scale it is on the contrary simple to a degree, as may be seen on the accompanying map.

The oldest rocks are exposed along eastern and north-eastern limits of the map and all along the road to Mashobra; they consist of fine-grained micaceous grey slates with occasional quartzite bands, originally described by Mr. Medlicott as the infra-Blaini or Simla slates. On the spurs either side of Annandale the prevailing dip is south-west-by-south which further east bends round to west-south-west. Near the upper limit of these slates there are some bands of a very trap-like sandstone or grit which I have only seen on the spur between Annandale

[1] The observations on which this account is based were made during a brief stay in Simla while preparing to start into the interior: the main features will be found fairly correct, but the boundaries of the rock groups have in many cases been sketched in without having been followed in detail.

and the glen and again near Sanjaoli, though it would probably be found in a corresponding position elsewhere. When weathered it is impossible to tell this rock from a decomposed trap, and even the unweathered rock has a very trap-like appearance, but its detrital origin is shown by the presence of rugged scales of mica arranged parallel with the bedding.

At their upper limit these beds become impregnated with carbonaceous matter, and in consequence the colour becomes darker and the streak changes from pale grey to black. They are succeeded by a remarkable and important set of beds, called the Blini (since changed to Blaini) by Mr. Medlicott, from their occurrence in the valley of the Blaini stream hich flows westwards from Solon.

The group was described by Mr. Medlicott as consisting of a pure hard limestone, generally pink, composed of thin beds aggregating 15 to 20 feet thick, and a conglomerate consisting of a matrix of fine-grained slates through which pebbles of quartz or slate were scattered. As applied to the group in the Simla neighbourhood, this description must be amplified, for, underlying the limestone and "conglomerate," there come carbonaceous slates, which usually weather white on the bedding surfaces, and below these comes another "conglomerate," the whole being probably about 200 feet thick.

As this group is one of great interest and, owing to its marked characteristics, great importance, it will be well to clear the ground by explaining that what has been called a conglomerate in the foregoing passage is not a conglomerate at all in the usual acceptation of the term. The rock consists of a fine-grained matrix through which are scattered blocks of slate and quartzite, as a rule angular or subangular, in some cases containing 8 or 10 cubic feet of stone. It is evident that a current sufficiently violent to move these blocks would have swept away the fine silt in which they were imbedded, while, *per contra*, any current sluggish enough to allow of the deposition of this silt would be impotent to move the small pebbles, to say nothing of the larger blocks which the now indurated silt encloses. The only possible explanation is that these fragments were dropped into a comparatively tranquil sea in which the silt was being gradually deposited, but there are only three known agencies by which this could have been affected, *viz.*, volcanoes, floating trees, or floating ice.

The rock in some respects resembles a volcanic breccia, and the resemblance is occasionally far more marked than appears in the Simla rock, but the steadiness with which the rock preserves its character over large areas, the frequent occurrence of well-rounded pebbles, the comparative absence of actually angular fragments, and more especially the absence of associated lavas or volcanic ashes, tell against this hypothesis. Floating timber is known to transport fragments of rock often of considerable size, but it is difficult to imagine how the enormous number of stones found in the Blaini boulder slate could have been thus transported, nor why the boulders should be confined to certain well-defined horizons; it would be strange too if out of the vast number of trees that would be required to transport all the blocks found in the Blaini group, all escaped fossilization, and the absence of carbonaceous matter from the boulder beds is very marked when they are compared with the associated slates.

The only hypothesis that remains is that of floating ice, which presents no difficul-

ties: floating ice is as capable of transporting waterworn pebbles as angular fragments without any limit of size; it melts away and leaves no trace beyond the fragments it may have carried with it, and, though the exact causes are not satisfactorily determined, it is a known fact that icebergs have formerly floated where none are now to be seen, and that regions now covered with perpetual snow and ice were once free from both. There is, consequently, no difficulty in accounting for the restriction of the transported blocks to certain definite horizons. Besides being the only hypothesis which does not land us in a difficulty there is a certain amount of corroborative evidence, for in 1884 Mr. C. S. Middlemiss discovered, in the Blaini group of the Naira (Neweli) valley in Eastern Sirmur, a pebble which was scratched in a manner very similar to that which is due to the action of glaciers, and I have myself seen in the neighbourbood of Simla several fragments which shew the same in a more or less obscure manner: in particular I may mention one block situated on the spur between Chadwick's falls and the glen which measures 4′ × 2′ × 1′ exposed; on one face it is smoothed and scored in a manner that can hardly but be due to glacial action. Taking everything into consideration we may, therefore, decide that when the Blaini group was being deposited, the spot now occupied by Simla was a sea on whose surface icebergs floated, melted, and dropped the stones, which they carried, on their surface or imbedded in their substance.

Returning now to the description of the rocks, the Blaini group, as defined on the accompanying map, consists at the base of a boulder slate; above this come carbonaceous slates which differ from those above and below by the manner in which they turn white on the weathered surfaces. The same feature is occasionally seen in the other carbonaceous beds, but in this particular band it is, so far as I know, universal. Above this again comes the original Blaini group of Mr. Medlicott. At the base it consists of a dark red slate which passes upwards into grey, occasionally blackish and carbonaceous, slate through which boulders are scattered, and above that there comes a thin-bedded pink limestone. It is this group of beds, not more than 60 feet thick in all, that is most easily traced (many of the exposures having already been recorded by Colonel McMahon[1]) and has been followed more completely by me than any other boundary. It enters the map in a side ravine flowing into the main stream below the Chadwick falls and can be traced over the spur into the Chadwick ravine; up the east side of this ravine it cannot be traced continuously, being hidden by surface debris; it may be cut by a small fault here, but this must be of later small throw, for the beds reappear in their proper position on the crest of the spur; they can be traced down into the glen, being hidden near the top and again near the bottom by soil cap, but, for the greater part of the way, can be traced practically continuously and closely follow one of the native footpaths. In the bed of the stream flowing through the glen the limestone is seen and is cut by a small fault which brings it into immediate contact with the red slates. It is again seen on the ascent from the glen and can be traced over the spur separating the glen from Annandale and runs down to where the road round this spur passes the spring which supplies the village of Gowai (of the map) with water. Here the limestone disappears, being apparently cut off by a fault; it cannot be traced across the Annandale valley owing to the rocks

[1] Records, G. S. I., X.

being hidden by sub-recent stream deposits, but may be seen in the stream bed and on the road which leads up the spur. East of Annandale it suddenly reappears, being evidently brought up by a fault. As the road rounds the end of the spur to turn back on itself, the red slates appear overlaid by the boulder bed and the limestone, here only represented by a few weathered blocks, the greater portion having apparently been removed by solution. The limestone and conglomerate can be traced with fair continuity over this spur along its western side, where again a native footpath follows it very closely into the ravines below the ridge. I did not follow it here, but it reappears below the ridge and can be traced up, passing below the Lakar Bazaar, on to the road round the north side of Jacko, where it crosses a spur and appears to run down into the valley west of Snowdon, but the ground is so covered that I was not able to trace it. Going along the North Jacko road the Blaini comes in once more, rather suddenly, as if brought up by a small fault, and runs past Snowdon, where there is a very characteristic exposure of the conglomerate just outside the guard-house. The limestone appears to run down under shady dell, but where not built on the ground is so covered with surface debris or spoil that has been tipped in levelling ground for roads or buildings, that it is impossible to follow the beds. However this may be, the Blaini is not again seen till just beyond the ravine where the upper and lower roads round Jacko separate. The beds are here brought up by a fault which shows itself as a line of springs. From here the Blaini can be traced across the upper road and up the spur to below the summer house in the grounds of Holly oak; here it appears to be again cut by a fault and is next seen just above where the road turns round the end of Jacko; there is only a small patch here, the beds cannot be traced in either direction, nor do they shew on either of the roads along the south side of Jacko. The limestone and conglomerate may however be found in the ravine below the Simla Rifle Club's range, west of and about level with the village of Sangati (Sanguti). I did not see it again till just above Shâman (Chaman) village where it can be traced practically continuously past Balahi, beyond which the limestone has been quarried. It runs down the west side of the Chota Chelsea spur and is seen near the Dhobi ghât below Chota Simla: hence it can be traced at intervals along the east slopes of the continuation of the Chota Simla spur till it runs out of the limits of the map.

It is noteworthy that the limestone is always well seen on the hill sides facing southwards, while on the northern face, which is covered with forest, the outcrop is always thin and often wanting. It is a known fact that the air contained in the interstices of the soil of a forest contains a larger proportion of carbonic acid gas than that of open ground; the water which percolates this soil would consequently become more impregnated with the gas and would be a more active solvent of the limestone than that which percolated the soil of the southern slopes. To this fact seems attributable the thinness or absence of outcrops of limestone on the northern slopes.

The lower conglomerate I did not trace with the same continuity as the upper one. It is seen in the Chadwick stream and again on the spur separating that from the glen. I next saw it where the road from the glen to Annandale passes over the spur, and it can be traced round the spur east of Annandale. On the Elysium spur

it crops out where the path leads up to the Elysium Hotel and again immediately above the house called Sylvan Hall; it is seen below Snowdon and again in the stream east of the forest, but whence it runs round towards the Mayo Institute. It appears on the Mall just above this place and can be seen running at first along, then below, the Mall till it crosses the ridge where the lower road rounds the end of Jacko. Southwards from here I did not trace it, but have no doubt that it continues in the same position relative to the upper conglomerate, and have consequently drawn it as doing so.

Above the Blaini comes a band of slates or schistose slates characterised by being more or less impregnated with carbonaceous matter: these were regarded by Mr. Medlicott as the same as some very similar beds called by him infra-krol, owing to their occurrence beneath the limestone of the Krol Mountain, which rises above Solon. But as it is not certain whether these or some similar beds seen at Jutogh represent the beds of the Krol Mountain, it will be better to describe them as the lower or Jacko carbonaceous slates. The upper limit is very indefinite, being only determinable by the presence or absence of the carbonaceous ingredient, and as this appears to be very capriciously distributed, it is probable that beds of the same age may have been mapped in one place as belonging to this and in another to the next group. Owing to the indefiniteness of the boundary I did not pay much attention to it, and as drawn it is for the most part conjectural; but, apart from some such explanation as is given above, or faults which I have not detected, it is impossible to account for some peculiarities in the boundary, which do not appear to depend on the dip of the beds and contour of the ground.

The essential characteristic of this rock is the presence of an appreciable proportion of carbonaceous matter. Occasionally, more especially where the rock is crushed, this is very conspicuous, gives the rock a sooty appearance, and produces a blackness of the hill sides which can be recognized from a distance as at Chadwick's falls and on the road along the south face of Jacko between the convent and Sanjaoli Bazar. Where the carbonaceous matter is in so large a proportion, the rock often assumes bright colours on its surface due to the efflorescence of various soluble salts produced by the decomposition of some of the mineral constituents of the rock. As a rule however the carbonaceous element does not make itself so conspicuous and is only recognizable by the black colour and more especially the black streak of the slate. It is also noteworthy that where these beds are exposed on a ridge and have been much weathered, the carbonaceous element appears in many cases to have been almost if not entirely removed.

The Jacko carbonaceous slates follow the Blaini very closely, except that they run over the ridge and down the Combermere ravine where they extend to near the Brewery, but are ultimately covered up by the general south-south-west dip of the beds: immediately below the first waterfall is some dark limestone which may belong to these beds.

Above these carbonaceous slates, which are about 300 feet thick, there comes a thousand feet or so of quartzites and schists for which I cannot do better than adopt Mr. Medlicott's name of Boileauganj quartzites. It is these beds that are seen for many miles along the cartroad, along the whole of the Mall, except near the bazaar and the road to Jutogh, as well as on all the southern and western spurs. The

greater bulk of the beds is quartzite, usually somewhat impure and schistose, but there is no small proportion of what must be called schist, occasionally garnetiferous. On the Boileauganj hill it has frequently a peculiar corrugated structure consisting of small rolls or larger rolls and giving the surfaces along which it breaks off an appearance which bears a distant resemblance to a bundle of sticks; hence the structure is called *bacillary*. These beds present very little of interest, so I shall pass on to the next group.

The upper or Jutogh carbonaceous slates and limestones are the newest rocks within the limits of the Simla station. They occupy three isolated patches—one, the largest, on the Jutogh hill, one on Prospect hill, and one small patch on the spur intermediate between these two. Like the Jacko beds, these are characterised by the presence of carbonaceous matter, but they differ in the prevalence of limestone: in the Jacko beds I have only seen limestone in one place, on the spur east of Annandale, while large quantities of limestone have been quarried, both for burning and as a building stone, from the Prospect and Jutogh hills. At Jutogh there appear to be three distinct bands of limestone, separated by schists and quartzite, but on Prospect hill only the lowest band seems to be left; this is overlaid by thin-bedded quartzite, and the hill is capped by a peculiar garnetiferous hornblende rock. Occasionally the garnets are absent, and it forms an intensely tough almost black rock, but usually a greater or smaller proportion of garnets are to be seen, which in places form fully a quarter of the substance of the rock: they occur for the most part as crystals of all sizes up to half an inch across, but where abundant there are also veins of garnet penetrating the rock. It is difficult to account for this rock; it has not yet been examined in detail, but the most probable explanation would be that it is an altered impure volcanic ash; if so, the absence of any similar or related rocks either on this hill or in a corresponding position at Jutogh is peculiar: the rock may be intrusive, but to the naked eye it has not that appearance.

The most marked feature in the geology of Simla and one that has been remarked on before now is the metamorphism of the higher beds accompanied by the absence of metamorphism in the lower beds. The grey Simla slates, though indurated, shew no signs of what could be called metamorphism, while on Jacko and the Boileauganj hill there are well-developed mica schists, and the limestones of Prospect hill and Jutogh are crystalline, and in the latter case contain well-developed crystals of graphite. [The rocks all down the southern slopes of the Simla hill shew more signs of metamorphism than the Simla slates, but less than the similar rocks of the ridge.] To a certain extent this is due to selective metamorphism, that is to say, the same, or a less, degree of heating has, owing to difference of composition, produced greater change than in the Simla slates, but this hardly seems enough to account for all the facts. In an unpublished paper by Mr. Medlicott on the geology of the Punjab, intended to be published in the Punjab Gazetteer, it is suggested that the heat may have been applied from above by the intrusion of a sheet of granite, since removed by denudation. This hypothesis has a *primâ facie* probability, for such sheets of granite have been observed in other parts of the Himalayas, and there is the remnant of one left on the very top of Hattu, where a very little more denudation would remove all trace of it, as Mr. Medlicott

supposed it to have done at Jacko. The hypothesis is however not free from difficulty, for there is no known outcrop of granite in the neighbourhood of Simla, and all round Jacko the rocks do not shew that metamorphism one would expect them to shew had a sheet of granite been pushed over them and retained its heat sufficiently to account for the metamorphism of Jacko. A third hypothesis would be that the metamorphism was due to a core of granite or other igneous rock having been intruded into the rocks but not yet laid bare by denudation. This is not impossible, for the porphyritic granite of the Himalayas appears usually to have eaten its way into the rocks by a process of fusion or solution by which the rock became incorporated with and replaced by the porphyritic granite. This is not the place to give the detailed observations on which the conclusion depends; suffice it to say that there are many facts which render it the only explanation possible in the case of the Chor and other intrusive masses, and granted this conclusion it is easy to see that there might be a great core of granite occupying the centre of the Simla hill without betraying itself either by actual outcrop or any conspicuous disturbance of the beds. Still the hypothesis is an improbable one.

Among these conflicting hypotheses it is impossible to pick out the true one, and probably the safest course will be to fall back on the first as a provisional conclusion. In any case, I do not doubt that selective metamorphism has had great influence, for I have noticed, in other parts of the Himalayas, that the rocks of the same age as those of the Simla hill are especially prone to metamorphism. Still this alone will not explain how the beds on the ridge have come to be distinctly more metamorphosed than those in the valley to the south of Simla, though they must originally have had practically the same composition.

The surface geology of Simla is of considerable difficulty, and I have not had time to make any but the most superficial observations of it. Almost everywhere the hillsides are covered by a soil cap consisting of a mixture of fragments derived from the underlying rock and of soil formed by the further decomposition of these fragments. This soil cap is in a state of progression down the slopes; part of this movement is cataclysmal in its nature, and takes place in the form of what are known as landslips, where a portion of the soil cap is suddenly carried a greater or less distance down the hillside and there rearranged; but besides this there is a slow though sure creep of the soil cap down the hill, which to a certain degree affects even what might be called live rock. This movement of the slightly disintegrated rock can be seen in almost every road-cutting. The rocks are all cut by more or less vertical joint planes, known as master joints, along which the rock splits off, as may be seen in any quarry. In the road-cuttings, however, it is seldom that these master joints shew a smooth face; as a rule, there are a series of smooth surfaces of various size, the upper projecting more or less beyond the lower where the rock has shifted along a bedding, or slightly inclined joint, surface. Where the rock has not been much split up, it is easy to see that these surfaces were originally continuous and have been broken only by the shifting of one part of the rock over the other without their evident relationship to each other having been obscured; but, by a gradual repetition of this process, the joint planes become completely obscured, and the rock gradually passes into an irregular aggregation of fragments constituting the typical soil cap.

It is to this gradual movement of the rock without any great breaking up, as well as to a cause presently to be mentioned, that the dip of the rocks appears to be always into the hill, and even into the minor spurs. It is a well known fact that, on the whole, hills are formed by synclinals and valleys along anticlinals, and the Himalayas are no exception to this rule, but it does not hold good to anything like the extent a casual observer might conclude from the fact that almost every dip he could observe pointed more or less directly into the hill, whatever the actual direction might be. This is in part due to the natural tendency of the broad, flat, rock fragments to arrange themselves at right angles to the direction in which they are slowly moving. In this way a weathered rock may be seen to dip into the hillside, though the true dip of the unweathered rock may be very different to that observed, and consequently it is never safe to trust to a dip observed in weathered rocks.

But even dips observed in solid rock that shews no signs of weathering and shews the true dip of that small portion of the rock, may give a very false idea of the true dip of the beds as a whole. Often along a hillside outcrops of rock are scattered, and all indicate a dip into the hill, though the actual direction will vary with the direction of the slope, while the form of the geological boundaries may shew that the general dip is fairly steady in direction and amount. The explanation of this may be seen in any deep cutting or stream bed: here the beds will be twisted about and contorted on the small scale to such an extent that whatever may be the general dip it will be easy to find some places that will give a dip in any selected direction. Now if this same rock is exposed on a hillside, in all places where the dip is down the slope or neutral (*i.e.*, at right angles to the direction of the slope), the rock will more readily weather into the soil cap than in those places where, owing to the dip being into the hillside, the fragments are able to give each other a more efficient support. In consequence of this we may naturally expect that it will generally be where the dip happens to be into the hill that the rock will be able to resist denudation so as to stand out from the general slope of the soil cap. In other words, the apparent dip into the hillside may be due to the direction of the slope and not the direction of the slope due to the dip. The Simla hill affords a very good instance of this. The general structure of the hill, as shown by the boundaries, is a very shallow synclinal whose axis bears north-east and south-west and is elevated to the north-east. In consequence of this the general dip is south-south-west or west-south-west, but, in spite of the assistance rendered by the numerous road-cuttings, the general impression left is that the rocks will everywhere be found dipping into the hill, whatever that direction may be. A careful consideration of the facts has, however, convinced me that this is only because it is to a very large degree only those dips which happen to be in that direction, which have a chance of being observed, the others being almost all obscured by soil cap.

In the valleys round Simla there are some sub-recent river gravels; they are not extensive in the area included in the map, but there is a large stretch of them extending beyond the limit of the map, in the stream which drains the southern slope of the ridge between Prospect hill and Jutogh. On the eastern side of the stream which forms the eastern boundary of the map, south from Sanjaoli, the same beds

are seen not in very great quantity, but shewing their nature very well: they may also be seen in any of the khuds, and the road along which the sewer is laid down to the waterfall shews very good sections of them. They are seen to consist of a *melange* of fragments all more or less angular and varying from some feet across to fine gravel, in fact showing many of the characteristics often considered peculiar to morraines. There is not however any reason to consider them of glacier origin, as they invariably show distinct stratification, a structure which, though not always wanting, is more conspicuous by its absence than by its presence in a true morraine. Stratification is essentially the mark of flowing water, and there can be no doubt that these deposits were formed by streams ; the angular nature of the debris being easily explained by the short distance it has travelled, while the mixture of large and small fragments is due to the steepness of the slope of deposition and the varying quantity of water which would flow at different times.

A point to be noticed is that these gravels extend in many cases right down to the bottom of the valleys, showing that these latter had been excavated to their present depth and then filled up by a deposit which is now being removed.

In the valley which leads southwards from Sanjaoli there is sufficient of the deposits left to form some idea of the original form of the surface which is now being destroyed. In the main valley there was a long sloping tract, the slope of this being somewhat steeper than that of the present stream bed. This "bottom" sent tongues up the small side valleys, the surface of these tongues having a slope steeper than that of the bottom and increasing up stream till at the summit it becomes 30°, as steep a slope as ordinary debris will lie at. This gradual steepening of the slope so as to form a concave surface is very conspicuous in the side ravines flowing from the east into the stream which flows south from Sanjaoli and is best seen from either of the roads round Jacko, as Sanjaoli is approached.

The explanation of the curve is not difficult. The slope is formed by debris deposited by the stream when its velocity is reduced below the limit at which it can transport the debris; but a large volume of water will acquire a given velocity on a smaller slope than a small volume; consequently, as the volume of the stream increases, the limit of velocity at which the debris must be deposited is reached on a gentler slope, and therefore the slope of the surface of the deposit diminishes as the stream increases in volume, *i.e.*, down stream. It is in the small side streams that the increase of volume is most rapid, relative to the volume of the stream, and consequently there that the curvature of the surface of deposit is most conspicuous, and in these side streams the effect enhanced by the fact that the large fragments are the first to be deposited, while the smaller fragments which are carried on require a less velocity and consequently a smaller slope to allow of their transport.

In trying to account for these high level gravels the most obvious explanation would be to suppose a change of level which caused the stream that had originally been eroding its valley to commence depositing debris in it, and then another change of level by which it was once more set to work at excavating. But similar deposits may be found in almost every valley throughout the Himalayas, and where not observable it is more probable that they have been entirely removed than that they never existed. It is impossible to suppose to suppose that every valley had its own special set of movements, and no general movement will account for all the

deposits, nor for the greater steepness of the surface of the old gravels than that of the recent stream beds and gravels.

When the gravels were being deposited the streams which flowed over their surface must have had a lower maximum velocity than the present stream acquires on a smaller slope; its maximum volume must therefore have been less or it must have been so loaded with debris as to be spread out in a shallow sheet and prevented from acquiring the velocity it otherwise would have done. In other words, the conditions then differed from those of the present day in that either (1) the rainfall was less or less unevenly distributed through the year, or (2) the disintegration of the rock was greater than what now takes place.

Taking the first of these, it might be supposed that the cutting down of the stream beds was due to the clearing of the hillsides by human agency. It is known that clearing the forest diminishes rainfall, but makes what does fall more unevenly distributed in time; moreover this effect is exaggerated by the increased rapidity with which the water flows off the hillsides. It cannot however be to any such cause that the observed facts are due, for they are just as conspicuous in the streams draining from the forest clad northern slopes of the hills as in those which flow from the bare grassy slopes with a southern aspect. Besides this as far as can be judged from the appearance of the stream beds the increased disintegration caused by the removal of the protecting forests has more than counterbalanced the increased volume of water at the maximum discharge, and in nearly every case of streams draining the southern slopes it will be found that, not far from their sources, deposition is outbalancing erosion and the stream has become on the whole a depositing rather than an eroding agent, so far as its lower reaches are concerned.

Apart from the clearance of forests we know of no change in the rainfall which would account for the alternation of conditions shewn by the river gravels, but we do know of a cause which would greatly increase the rate at which the rocks would be disintegrated, and at the same time would probably have some effect in diminishing the rainfall. There are many reasons, which need not be entered into here, for believing that the glacial epoch was felt in India as in Europe. There is no certainty as to the extent to which the snow line was lowered, but there is good reason for believing that in places glaciers descended to 4,000 feet, if not lower. If we only suppose the snow line to have been depressed 5,000 feet, the whole of the Simla hill would have been cleared of forest, and disintegration proportionately increased; at the same time this great accumulation of snow could not but have had some effect in diminishing if not abolishing the monsoon rains, but as this may have been counterbalanced by the supply of water derived from the melting of the snow in summer, we cannot be sure, though it is very probable, that the maximum volume of flood was less than now.

The hypothesis that the formation of the gravels dates from the glacial epoch has the merit of explaining all the facts and of not conflicting with any other known facts. It allows of a mild climate during which the valleys were excavated to their present depths, then a period when disintegration was increased, both directly by the increased cold and indirectly by depriving the hillsides of their protecting forest; during this period possibly the actual volume, and certainly the volume of the streams relative to the burden cast on to them decreased, and in consequence

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Two boys, who saw it fall, said they were startled by a report like that of a gun, looked up, and saw the stone just before it reached the earth. After it fell "a grumbling, like thunder, went on for some time." The meteorite fell on a stone and was broken into pieces: the boys did not go near them for some time from fear: when they did the fragments were cold. The direction of the fall is said to have been from west to east.

"The noise was heard in, and reported from, two places at a distance from the spot where the meteorite fell. Mr. Sturt, Assistant Commissioner, wrote to me from Mahroni, where he was then encamped, that, at 10-30 A.M. on the 7th April, he heard a sound like thunder, went outside his tent to find a clear sky and no signs of a storm, and found the people about wondering what the noise meant. Mahroni is 9 miles 2½ furlongs north-east of the spot where the meteorite fell. The police officer of Dudhaie, 10 miles 2 furlongs due west, reported that at the same time (he says 10 A.M. but had no watch) he heard a sound like a heavy cart going over a rough road; went outside his station to see what the matter was, and could see nothing. He reports the sky to have been perfectly clear at the time."

The Deputy Commissioner remarked that as the meteorite fell on a stone the fragments were scattered and many have probably not been found. Seven were secured by him, one of which subsequently broke in two, making eight in all. These have been sent to the Geological Museum in Calcutta: they respectively weigh—

A.	128·04	grammes.	
B.	82·23	"	
C.	56·40	"	
D.	38·21	"	
E.	28·77	"	
F.	22·32	"	
G.	13·78	"	
H.	2·09	"	
TOTAL	371·84	"	(about 13 ounces avoirdupois).

The fact that there are but two pairs that admit of being joined together shows that, as surmised by Colonel Liston, many fragments are wanting. Those sent have the usual black crust on the original exterior, and are composed of a fine-grained, grayish-white stony mass, through which a small proportion of substance with metallic lustre is disseminated, chiefly in very thin seams, but partly in minute grains. The examination of a few milligrammes of this showed that riccoliferous iron is the main constituent, but troilite and schreibersite are both, apparently, present also. The specific gravity of the largest fragment of the meteorite is 3·546.

deposition commenced. Then came an amelioration of climate during which disintegration gradually decreased both directly and indirectly, while the maximum volume of the stream increased, if not absolutely at any rate proportionately to the load it had to carry, and in consequence erosion once more set in, which has continued to the present day.

This filling of the valleys has not caused any considerable hydrographical change in the area under consideration, but the two waterfalls in the Combermere glen are both due to a small diversion of the stream. In both cases the old river bed ran west of the present one, but is now filled up with gravel, the stream when it began once more to erode choosing a slightly different channel to that it had originally occupied cut down to a saddle on the buried spur from which it could not work down to the old course; at the same time the more rapid removal of the soft gravels below the spur caused those spreads of gravel with a rapid drop over a rocky barrier at their lower end which are now known as the first and second waterfalls.

The economic geology of the Simla hill is very limited: building stone is naturally in abundance and of a quality good enough for rubble masonry; where dressed stone is required the limestone of Prospect hill or Jutogh is used.

A certain amount of pottery clay is found on the slopes, some of the spurs running north from Simla: it appears to be confined to the neighbourhood of the carbonaceous slates and to be largely composed of the insoluble residue of the limestones associated with them. A large deposit existed on the north slope of Jutogh, but has been almost entirely removed to make bricks and tiles for the new offices in Simla. Another large deposit appears to exist on the Summer hill spur beyond where the road rounds its northern end, but at present it is only dug to make a few gurras, flower pots, &c. Another place where clay is found and worked is on the eastern slopes of the spur east of Annandale. Here there are several potters' houses dotted along the hillside.

The water-supply of Simla has for many years been a source of difficulty, and water is now brought in by pipes from the Mahasu ridge.

Note on the "Lalitpur" Meteorite, *by* F. R. MALLET, *Superintendent, Geological Survey of India.*

We have received from Colonel J. Liston, Deputy Commissioner of the Lalitpur district, in the North-West Provinces, several pieces of a meteorite which fell in the district during the present year, together with such information as could be collected about the fall. It appears that the meteorite fell at 10-30 A.M. on the 7th April, on the boundary line between the villages of Jharaota and Nyagong, in parganna Maraura; approximately, therefore, in latitude 24° 27′, longitude 78° 39′.

Two boys, who saw it fall, said they were startled by a report like that of a gun, looked up, and saw the stone just before it reached the earth. After it fell "a grumbling, like thunder, went on for some time." The meteorite fell on a stone and was broken into pieces: the boys did not go near them for some time from fear: when they did the fragments were cold. The direction of the fall is said to have been from west to east.

"The noise was heard in, and reported from, two places at a distance from the spot where the meteorite fell. Mr. Sturt, Assistant Commissioner, wrote to me from Mahroni, where he was then encamped, that, at 10-30 A.M. on the 7th April, he heard a sound like thunder, went outside his tent to find a clear sky and no signs of a storm, and found the people about wondering what the noise meant. Mahroni is 9 miles 2½ furlongs north-east of the spot where the meteorite fell. The police officer of Dudhaie, 10 miles 2 furlongs due west, reported that at the same time (he says 10 A.M. but had no watch) he heard a sound like a heavy cart going over a rough road; went outside his station to see what the matter was, and could see nothing. He reports the sky to have been perfectly clear at the time."

The Deputy Commissioner remarked that as the meteorite fell on a stone the fragments were scattered and many have probably not been found. Seven were secured by him, one of which subsequently broke in two, making eight in all. These have been sent to the Geological Museum in Calcutta: they respectively weigh—

A.	. . . . . 128·04	grammes.	
B.	. . . . . 82·23	"	
C.	. . . . . 56·40	"	
D.	. . . . . 38·21	"	
E.	. . . . . 28·77	"	
F.	. . . . . 22·32	"	
G.	. . . . . 13·78	"	
H.	. . . . . 2·09	"	
TOTAL	. 371·84	"	(about 13 ounces avoirdupois).

The fact that there are but two pairs that admit of being joined together shows that, as surmised by Colonel Liston, many fragments are wanting. Those sent have the usual black crust on the original exterior, and are composed of a fine-grained, grayish-white stony mass, through which a small proportion of substance with metallic lustre is disseminated, chiefly in very thin seams, but partly in minute grains. The examination of a few milligrammes of this showed that riccoliferous iron is the main constituent, but troilite and schreibersite are both, apparently, present also. The specific gravity of the largest fragment of the meteorite is 3·546.

ADDITIONS TO THE MUSEUM.

FROM 1ST APRIL TO 30TH JUNE 1887.

Copper from the Beshi Copper mine, Jyo, Japan.
PRESENTED BY MR. K. SUMITOMO, OSAKA.

Calcareous aggregation upon an old anchor found at a depth of 4 fathoms in Colombo harbour, November 3rd 1886. (Illustrating the formation of shell limestone).
PRESENTED BY MR. F. J. DALBY. (?)

Specimens of rock crystal; beryl, in quartz; beryl, with mica in quartz; garnet, in mica schist; and garnets, from different localities in Jaipur.
PRESENTED BY THE HONORARY SECRETARY, JAIPUR MUSEUM.

ADDITIONS TO THE LIBRARY.

FROM 1ST APRIL TO 30TH JUNE 1887.

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„ VI, Abth. IV, Võgel, lief. 16-17. (1887).
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July 18th, 1887.

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RECORDS

ERRATA.

Records, Geological Survey of India, Vol. XX, Part 3.

Page 121, line	8 from top,	for *thirty* read *thirty-three*.
" 122, "	15 "	after *canals* add *Jour. Roy. As. Soc. Lond. XX*, 326, 1863.
" 123, line	3 "	for *Tovla* read *Toula*.
" 123, bottom	line,	" *first* " *this*.
" 136, line	2 from top,	" *Bandin* " *Bandni*.
" 137, "	25 "	" *Matkori* " *Malkori*.
" 137, "	42 "	" *slates* " *states*.
" 144, "	5 "	" *rugged* " *ragged*.
" 145, "	35 "	erase the word *later* between *of* and *small*.
" 147, "	4 "	for *forest, but* read *forest hut*.
" 148, "	5 "	" *or* read *on*, and erase the word *and*.
" 148, lines 36 &	38 "	erase brackets.
" 150, line	15 "	for *dips* read *a dip*.
" 153, "	20 "	" *slopes, some*, read *slopes of some*.
" 154, "	3 from bottom,	for *riccoliferous* read *nickeliferous*.

glomerate, cemented by calcareous mud, which resembles some of the conglomerates in the Mandháli series on the Deoban ridge. This fact, combined with the occurrence of carbonaceous slates in the upper part of the Naira valley, where they appear to overlie the limestone, led me at the time to regard the latter as of Deoban, rather than Krol age.[1] Subsequent consideration has, however, led me to doubt this

[1] I shall show later on that the two limestones are distinct in age.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1887. [November.

Note on some points in Himalayan Geology, *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.*

The observations on which the following remarks are based were made partly in company with my colleague Mr. C. S. Middlemiss, partly by myself alone during the spring of 1884. During a brief tour in the lower Himalayas my attention was directed to an attempt to elucidate some doubtful points in, and as far as possible to complete, the sequence of sedimentary formations in the lower Himalayas. As a consequence very little detailed mapping was done, and that only where the structure of the hills appeared to be simple enough to allow of some definite conclusion being arrived at as to the superposition and relation of the rock groups. Nothing was published at the time, as the conclusions arrived at were for the most part provisional and liable to alteration. Since then there has been no opportunity of correcting or amplifying them, but on consideration there seem to be some points of sufficient interest and importance to warrant publication.

The limestone of the Naira valley.—In the valley of the Naira river (Neweli of map) in eastern Sirmúr a massive limestone is exposed, some of the beds having a strong sulphurous odour, while near the base are some oolitic bands. As regards lithological appearance, it does not differ markedly from either the Krol or Deoban limestones, it extends on either side of the valley and forms the Juin peak on the north, and the hill which rises above Dugána on the south. At the Juin station it is cut off by a combination of a uniclinal fold and faulting; to the south it is cut off by denudation. On the summit of the peak above Dugána there is a limestone conglomerate, cemented by calcareous mud, which resembles some of the conglomerates in the Mandháli series on the Deoban ridge. This fact, combined with the occurrence of carbonaceous slates in the upper part of the Naira valley, where they appear to overlie the limestone, led me at the time to regard the latter as of Deoban, rather than Krol age.[1] Subsequent consideration has, however, led me to doubt this

[1] I shall show later on that the two limestones are distinct in age.

conclusion, the superposition of the carbonaceous slates may well be due to disturbance, for the beds are very much disturbed in the upper Naira valley, while the limestone conglomerate is a rock which might naturally be expected to occur as the bottom bed of a formation resting unconformably on massive limestone.

The Blaini group in the Naira and Bangál valleys.—Below the limestone there come grey slates in which the Blaini limestone and boulder bed occur; it was traced from the crest of the ridge south of the Naira valley into the Bangál valley, being much cut up by faults; it is carried up one side and down the other of the ridge which separates these two valleys by a series of step faults, which are especially marked on the south side of the ridge. These faults run in the direction of the boundary of the massive limestone on the Juin hill, and in that rock seem to die out as faults, and become converted into a uniclinal fold.

The group is of the same type as that first described in the Blaini valley, consisting of a single band of pink limestone and conglomerate, the latter containing many fragments of volcanic rock derived from the volcanic series which will presently be mentioned. In the bed of the stream which flows east of the village of Bombhil, close to its junction with the Naira there is an exposure of the boulder bed which distinctly marks its mode of origin. The matrix is laminated and the laminæ are seen to be bent down under, and to arch over, the larger included fragments, showing that these must have been dropped into a tranquil sea in which the fine silt of the matrix was being deposited.

It is not necessary to recapitulate here the reasons why I regard the boulders as having been dropped by floating ice, but I may mention that where the boulder bed crosses the Naira valley we discovered a pebble (now in the museum) showing striations similar to those usually ascribed to glacier action. It is, however, necessary to notice the extraordinary similitude to a volcanic breccia exhibited by the Blaini "conglomerate" on the Juin ridge: not only are the included fragments mostly of volcanic rock, but the matrix itself very strongly resembles an impure volcanic ash. It is not natural to suppose that this rock should here be of volcanic origin, while elsewhere, and in general, such an origin can be shown to be untenable, so we must look to some other cause for the resemblance. This I imagine to be the same as explains the other features presented by the rock, *viz.*, a severe climate. Under the climatic conditions which now prevail even at an altitude of six or seven thousand feet, the volcanic beds disintegrate, principally by the decomposition of their constituent minerals, but it is conceivable that, under a climate severe enough to produce floating ice at the sea level, the disintegration of the rock would be more rapid than the decomposition of its constituent minerals; in this case it would be difficult to distinguish the sandy material so produced from the ash directly produced by a volcanic eruption. I know of no observations confirmatory of this hypothesis or the reverse, but it seems a possible one, and at any rate does not conflict with conclusions arrived at on independent grounds.

The volcanic beds and "lower Chakrata" quartzites of the Bangál and Naira valleys.—Under the Blaini beds, but separated from them by slates, comes a series of volcanic beds, consisting of felsitic lavas and ashes, underlaid conformably by purplish red and mottled quartzites, with interbedded schistose slates. This series of beds I have no hesitation in correlating with what I have described as the Lower Chak-

ratas, and overlying volcanic beds of Jaunsar, as they resemble each other, not only in lithological character, but in the order of superposition of the beds.

Regarding this, the most important fact to be noticed is that part, at least, of the volcanic beds is of subaërial origin. In proof of this statement, I appeal to a specimen, preserved in the Imperial Museum at Calcutta, where portions of two distinct lava flows are seen to include between them a string of well-rounded, water-worn pebbles. Were these only of lava, it would not indicate more than an isolated volcanic island, which need not have been raised more than enough to bring its summit within reach of the breakers, but the majority of the pebbles are of vein quartz, which must have been derived from some land surface of non-volcanic rocks.

On the north side of the Bangál valley below the village of Lána there occurs, far below the volcanics, a bed which, like the Blaini "conglomerate," can hardly but be of glacial origin. It consists of rounded, waterworn boulders of quartzite, imbedded in a fine grained, red coloured, subschistose matrix. This rock was not seen *in situ*, so there is some doubt attaching to its geological position, but it occurs in large fragments just where a continuously descending section of the red quartzites and volcanic beds is faulted against the Deoban limestone. It is important to note that this is not a volcanic bed; it is separated from the volcanics by the "Lower Chakratas" and a considerable thickness of schistose slates that underlie them; and the well-rounded condition of the boulders, which range to over a foot in diameter, shows that they have been waterworn.

In northern Jaunsar I have seen a very similar bed at about the same horizon; its position is represented by the southernmost of the two blue patches in Jaunsar on the map illustrating Col. McMahon's paper on the Blaini groups and central gneiss of the Simla district.[1]

Relation of the Blaini beds to underlying rocks.—On the north side of the Bangál valley the volcanic series is overlaid by about 1,000 ft. of subschistose grey slates. On the south side there are at most a few hundred feet of slates between the Blaini and the volcanic beds, and these appear to belong rather to the Blaini than the volcanics. On the crest of the Juin ridge the volcanics do not seem to have thinned out appreciably, but down the slope into the Naira the thickness of them lying between the purple quartzites and the Blaini slates diminishes, till in the Naira valley the volcanics have disappeared entirely.

It is possible that this may be due to faulting, but the recognizable faults are almost all dip-faults, which would not affect the apparent thickness of strata between the purple quartzites and the Blaini group, while the beds lie too flat for their appearance to be due to a squeezing out of the rocks in consequence of contortion; nor, were such to take place, would one expect the volcanics to be squeezed out rather than the overlying slates.

It might be supposed that the thinning out of the volcanics represented their original limit of extension, but that is hardly probable, for a band of limestone is inter-stratified with them throughout Jaunsar, while, as I have already shown, they are of subaërial origin in Bangál valley. It is reasonable therefore to suppose that this locality marks the neighbourhood of a focus of eruption, and a sudden thinning out in its neighbourhood is not what would be expected.

[1] Records, G. S. I., X, p. 222.

A more natural explanation is to regard the thinning out of the volcanics and overlying slates as due to their removal by denudation, previous to the deposition of the Blaini. This view derives some support from the presence in the Blaini boulder bed of angular fragments of volcanic ash, which must have been indurated and converted into solid rock previous to their transport to the locality in which they are now found.

Termination of the ridge between the Naira and Bangál valleys.—Along the termination of this ridge, where it slopes down to the Tons, and in the Naira valley, there is exposed a grey slate series containing a band of blue limestone about 300 feet thick. These resemble the slates and interbedded limestone of Southern Jaunsar which were described by me as "Upper Chakratas." West of the Tons they appear to pass under the "Lower Chakratas," and the section upwards from the latter is a normal one. This apparent reversal may be due to disturbance, but there is every possibility that the section in Jaunsar on which I based my conclusion was inverted. The question of which of the two, the slates and limestone or the red quartzites, is the newer, remains to be decided by further survey.

Unconformity at the base of the infra-Krols in the Valley of the Minas gádh (Suinj R. of map).—The whole northern side of this valley appears to consist of limestones; possibly near the top some other series may come in, for I did not examine the hillside, but certainly the greater part of the northern side of the valley, near the Tons, is composed of a limestone series, which I see no reason to doubt is the same as that of the Deoban hill. The limestone extends south of the stream and can be seen faulted against the purple quartzites of the "Lower Chakrata" series. At the head of the valley both limestone and quartzites are overlaid by a band of black carbonaceous slates and limestones, which is also seen in the Gerwáni hill, resting on the grey slates that overlie the volcanics. This carbonaceous series can be very distinctly traced along the hillside, and, though it appears to be faulted in the Minas valley, does not seem to be cut by the fault which separates the limestone and quartzite series lower down, at any rate not to the same degree. This would point to the boundary fault being of great age, and to a complete removal of the Deoban limestone south of it previous to the deposition of the black carbonaceous slates, and consequently to a great unconformity at their base. These black carbonaceous slates can be traced into continuity with similar beds in the Chepal valley, where there can be little doubt that they represent the infra-Krols of the Simla region.

The Mandhāli beds of the Chor and Chepal.—On the eastern side of the Chor mountain there are several exposures of a boulder bed, very similar to the Blaini conglomerate in physical characters, but without the characteristic associated limestone. The most southerly exposure is on the north side of the Minas valley a little below the hamlet of Dím (Demi). The boulder beds are here interstratified with blue limestone, a feature also noticed in the Mandhális of Jaunsar, and lie between the massive, presumably Deoban, limestone and the carbonaceous slates. This "conglomerate" is not continuous in this position, as it is wanting near the village of Deothali (Thotali), but it is present on the Cheti (Baiti) ridge.

Between this and Chepal the rocks are too disturbed for their structure to be determinable in a rapid survey, but east of Chepal the boulder beds recur in the

same position as further south, *viz.*, between the massive limestone and carbonaceous slates. The beds are a good deal cut up by faults, which, added to their variable nature, renders it difficult to determine a really characteristic section. One which was roughly measured by me gave a band of conglomeratic slates, underlaid by 100 feet of non-conglomeratic slates, below which were conglomeratic bands occurring with quartzites through 200 feet, while 50 feet below these came a band of pink limestone, resembling the Blaini limestone.

This exposure is referred to by Col. McMahon, who declared that "it is beyond all reasonable doubt that the rocks here seen are the Blaini rocks."[1] I think it is beyond all reasonable doubt that they are the same as my Mandhális of Jaunsar, which they resemble very strongly in physical character and in their superposition on a massive limestone series.

Whether the Blaini and Mandháli rocks are of the same age or not I shall leave for a separate paper on the boulder-bearing slates of the Himalayas, but it is necessary here to remark that I could find no proof of unconformity between the boulder beds and carbonaceous slates; but the irregular appearance of the former points to an unconformity of both on the Deoban limestone. The same is proved by the presence of fragments of the latter rock in the former, and in this it agrees with the Mandhális of Jaunsar.

Before leaving this subject I must notice that in the exposure east of Chepal there is a small patch of a rock which very strongly resembles a volcanic ash. The rock is exposed on the very crest of the ridge and is almost immediately cut off by a fault; what remains is very much decomposed, but I notice it, as this is the only case I have seen where a rock associated with the boulder beds has presented more than the most superficial resemblance to a volcanic rock.

The volcanic rocks of the infra-Krol series.—On the spur south of the Minas gádh, leading east from the Chor, in the Deora valley of Jubal, on the Narkanda-Sungri ridge and on the Lambatách ridge between the Tons and the Pabar, I found volcanic beds associated with the black carbonaceous slates. These beds differ in age and character from those of the "Lower Chakrata" series; the specimens have not yet been examined in detail, but, speaking broadly, it may be said that they are of a more decidedly basic character than the Lower Chakrata volcanics.

These are the same beds as are described from the Sutlej valley[2] by Col. McMahon, who correlates them with the volcanics of Dalhousie and Cashmir.

The gneissose granite of the Chor.—As the Chor was deeply covered in snow when I was in that neighbourhood, I did little more than take a passing glance at the eastern margin of the granitic intrusion. The intrusive nature of the gneissose granite having been proved already, it is not necessary to consider this point in detail, but I may say that the manner in which the boundary of the granite cuts across the bedding of the adjoining sedimentary rocks, as well as the numerous inclusions of schist and quartzite, make it very evident that the rock of the Chor is a granite by origin.

I was, however, able to make one observation which has an important bearing on the mode of intrusion of the granite. On the spur south of the Minas gádh the

[1] Records, G. S. I., Vol. X, 210. [2] Records, G. S. I., Vol. XIX, 67.

black carbonaceous slates are overlaid by the volcanic beds noticed above, here changed by contact metamorphism into hornblende schists and mica traps. On the spur north of the Minas gádh no trace of these rocks can be seen, but in their place is an exposure of a rock which only differs from the porphyritic rock of the Chor generally, in that the matrix is highly hornblendic, and consequently dark coloured, thus throwing up the porphyritic crystals of orthoclase with great distinctness.

I do not see any possible explanation of these facts unless we suppose that the granite dissolved and absorbed the rocks, whose position it now occupies. On this supposition its locally hornblendic nature, where it replaces hornblendic rocks, is easily explicable, while the very slight disturbance of the surrounding beds, as well as the steady dip towards the Chor, are inconsistent with the supposition that the granitic intrusion was either the cause or consequence of disruption of the sedimentary beds.

The gneiss series of the Upper Pabar valley.—In the upper reaches of the Pabar valley and its affluents there is exposed a series of beds which, whether we have regard to their lithological structure or their mode of origin, must be classed as a gneiss series. For the most part the beds are gneiss, but they vary in one direction to nearly pure felspar, in the other to a very slightly felspathic mica schist; some beds are schistose greisen, and there are a few of metamorphic quartzite whose sedimentary origin is easily recognizable. The foliation is parallel to the bedding planes, and the whole is most palpably metamorphic, using that term as opposed to intrusive, and without reference to whether these rocks ever were or were not ordinary sediments, such as those the slates have been formed from.

Many of the beds of gneiss contain porphyritic eyes of orthoclase, sometimes two or three inches in length. As regards internal structure, they resemble the porphyritic crystals of the gneissose granite, being composed of a single twinned crystal of the Carlsbad type, but they differ in their external form, which is lenticular, and in their invariable arrangement, with their greatest diameter along the plane of foliation. Doubtless it was by fusion of this rock that the intrusive porphyritic granite originated.

The position of this rock is very clear, for the beds lie very flat for the Himalayas. It unconformably underlies a series of red quartzites, which, near the Búran (Borenda) pass, are overlaid by beds containing hornblende schist. I have little doubt that these represent the "Lower Chakratas" and overlying volcanic beds, the lithological similarity between the quartzites being especially striking.

Arkose beds of the Lambatách ridge.—On the Lambatách ridge there is exposed a series of beds presenting many points of interest which, owing to the coming on of the monsoon, I was not able fully to investigate. The beds consist in part of the fine grained felspathic quartzites which extend into Bawar, and were there described by me as the Bawar quartzites. But below these comes a great thickness of more or less schistose beds containing granules of felspar. In the Kotigadh (Kunjado R.) the rock is at first sight difficult to discriminate from the porphyritic granite, which it resembles also in its mode of weathering. But on closer examination it is seen to decompose more readily, and a close examination will generally show that the felspar consists of broken crystals, while not infrequently small pebbles may be detected. Another feature which separates it from the gneissose granite and unites it to the felspathic grits is the abundance of granules of pale blue transparent quartz.

These rocks pass upwards into black carbonaceous slates and limestones, associated with volcanic beds, which in all probability are the same as the *infra*-Krol carbonaceous slates. If this be so, the arkose cannot have been derived from the porphyritic granite, which is found intruded among carbonaceous slates on the Chor and in the Deora valley, but must have been derived directly from the archæan gneiss.

It seems probable that these arkose beds indicate a severe climate, as it is evident that the disintegration of the rock from which they were derived must have been more rapid than the decomposition of its constituent minerals. This view receives some confirmation from sections exposed in the road cuttings in the Deota forests; some of these beds of coarse grit have scattered through them boulders of quartzite, ranging from a foot and more in diameter. With so coarse-grained a matrix this does not prove glacial origin, unless it could also be proved that the beds were not of subaërial origin; for large boulders may often be rolled along the surface of a much finer deposit, where the latter is formed by shallow streams. But, as there is no direct evidence of a subaërial origin of the felspathic grits, it seems natural to take these boulders, combined with the undecomposed felspar, as indicating a severe climate.[1]

It may be noticed that the arkose beds appear to hold much the same relation to the carbonaceous slates as the presumably Mandháli boulder slates do to the carbonaceous slates of the Chor and Chepal. The latter, there is every reason to believe, are of glacial origin.

Crystalline *and* Metamorphic Rocks *of the* Lower Himalaya, Garhwal and Kumaun, Section II, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*

In the last number of the "Records" I described Dudatoli Mountain from a petrological and structural point of view. The present paper will be devoted to a short account of some ancient Rhyolites and associated rocks which adjoin the Dudatoli area on the east. Their geological importance depends partly on the fact that they are the first representatives of an acidic type of lava that I have met with in British Garhwal, partly on their situation among a set of formations sharply marked off from the neighbouring schistose area, and chiefly on the circumstance that among them exists a transitional form, connecting petrologically these ancient acidic lavas with the gneissose granite of the Dudatoli ridge. This is the first time that any of the gneissose granites of the Himalaya have been shown to be connected with a subaërial lava flow: and the coincidence seems to finally clinch the argument and set at rest the controversy concerning the eruptive character of the gneissose granite. Strictly speaking however, it only demonstrates that a portion of the gneissose granitic material was drawn upon by volcanic vents; and, as this

[1] I have found that gneiss and granite disintegrate into felspathic sand, in which the felspar is undecomposed, at elevations of 14,000 feet and over in Ladák. I have never seen a material which could consolidate into arkose at the lower elevations, up to 10,000 feet, of the outer Himalayas.

material may have come from a source vertically far above where the Dudatoli ridge now is, the deeper-seated magma now represented by the Dudatoli rock may never have had much of a demand made upon it by the volcanic action above, to rush into eruption, and so may never have possessed much motion relatively to the intruded rock. I will describe these erupted lavas, and the formations among which they occur, by reference to a locality where I first hit upon them.

LOBAH VOLCANIC ROCKS.

The map facing page 142 of the last number of the "Records," at its east margin, is contiguous to a great faulted boundary running nearly north by west as far as the Dewalikhal pass, and then veering further west as it skirts the north-east portion of the Dudatoli massif. This fault can be traced for 20 or 30 miles forming a great dividing line between the old schistose series among which the gneissose granite is insinuated, and the younger set of lavas and more nearly related formations with which the gneissose granite is approximately contemporary. A few miles from the fault these younger formations, in the vicinity of Lobah, have a fairly steady dip towards the east-north-east; but near the fault they are forced into a few close folds, with subordinate faulting, nearly parallel with the great fault itself.

The strike of these rocks may be put down as very nearly N.N.W. to S.S.E. They, therefore, cut directly across the strike of the schistose series, which is roughly W.N.W. to E.S.E.

The lowermost of the younger set of formations, east of the fault, is a limestone of dark blue-grey co'our, and massive appearance; only differing from previously described limestones of this type by the presence of nodules of chert in some of its upper layers. This formation peeps out from underneath the volcanic rocks in longer or shorter anticlinal domes, and is well exposed in the stream beds which join the Ramganga from the east. I hazard nothing at present concerning its age. A short thickness of glassy looking quartzite is superposed in some sections.

A great unconformability, with attendant conglomerate, ushers in the volcanic rocks. The conglomerate, which it will be convenient to call the Lobah conglomerate, varies considerably within a few miles of outcrop; and vertically also it changes very rapidly. Its strongest feature is a large, well-rounded, torrent-boulder bed; the pebbles being from a few inches to a foot in diameter. They are chiefly quartzite, of that hard and glassy kind found immediately beneath the conglomerate. I found no pebbles whose constitution could be called a quartz-schist. A few limestone pebbles were occasionally present. The whole is coherent, as a massive and exceedingly hard rock, with a little cementing material of coarse quartzose and slightly calcareous substance. In certain localities the pebbles are scarcer, and the basal conglomerate is then a conglomeratic, faintly schistose slate, or ashy slate. It is sometimes absent altogether, and the limestone is directly overlaid by the faintly schistose slates. South of Lobah, however, the section is complicated by the introduction of a more decided volcanic element. Along with the larger pebbles there appear angular fragments, and the matrix of the rock changes and assumes a hard dark-green compact aspect suggestive of a felsitic nature. This gradually frees itself from the rounded pebbles, the angular fragments remaining, and more and more

resembling brecciated portions of a flow similar to that of the matrix, but of a lighter tint. Further south, near Suini, purer rhyolitic rocks set in; the whole series tending to become thicker in this direction. There are now displayed several varieties of a compact type, and others slightly vesicular. In the small stream ½ mile N.E. of Marwara village, near Lobah, I found the rock mentioned above as intermediate between the ancient rhyolites and the gneissose granite of Dudatoli. The whole of these volcanic rocks, together with some subordinate beds of dark grit, ashy grit, brown and yellow non-schistose quartzite, and some steatitic slates, cover the massive limestone as a skin, down the face of the hills on the east side of the Ramganga river. Owing to this position, modified by faulting, it is sometimes difficult to trace their exact stratigraphical relations; but they seem to merge upwards, with sometimes an intervening thin band of cream-coloured limestone into slightly schistose slates and schistose ashes. The latter, in many places high up in the series, become very basic in character; whilst the whole of the series is entirely different from the schistose series west of the great fault. I may here mention that N.W. of the Dudatoli massif another set of acidic lavas are found along the ridge 3 miles west of Dobri trigonometrical station. There seems no doubt that they are of the same age as the Lobah flows.

At this point it will be convenient to close the description of these rocks, so far as their field relations go, and to describe them more minutely by means of a set of specimens. These and their accompanying microscope slides will be referred to by their registered number. Thus labelled, they are now in the Geological Survey Museum, Calcutta.

Specimen No. $\frac{7}{118}$.—This rock was found near Sainji, about ¾ mile on the pathway to Suini M., Sp. gr. 2·70. Contains 79 per cent. of silica. Before the blowpipe it fuses with difficulty on the edges of thin splinters. In the hand it is a compact rock of a pale grey-green colour, sometimes flesh-white, and altered much by weathering. It breaks with a flinty fracture. It appears dotted over in many place by white spots about the size of pin-heads. These, which I first thought were spherulites, are small gas-pores, filled with an alteration product in the form of amygdules.

Microscopical.—Under the 1 inch objective the field of the microscope is filled by an almost structureless ground-mass, containing no porphyritic crystals, or included fragments of any kind. There is only a faint indication, here and there, of a gathering of the material of the ground-mass into hazy clusters. The gas-pores appear merely as round holes in the slice. Under the ¼ and ⅛ inch objectives the ground-mass is seen to possess a clear base, which, with ordinary transmitted light, cannot be split up into grains, but appears uniformly amorphous. Through it are scattered in the wildest profusion and without any order a countless number of microlites, very small, and of irregular shape. They are sometimes more or less rounded, sometimes elongated needles; but more often of an irregular form longer one way than another. There is no spicular arrangement, as in the Arran pitchstones, no dendriform structure, and no trace of spherulites. The only thing noticeable is that in some places the microlitic groupings are denser than in others. The microlites are pale yellowish green in colour. Minute specks of opacite are only sparingly represented, except in connection with the gas-pores, which are more or less

lined by them. The microlites cannot be regarded as having any claim to a crystalline structure; for when the nicols are crossed, they have no influence on polarized light. Their outline can then only dimly be seen through the base, which becomes divided up into irregular polygonal patches of light, and dark blue-grey colour, whose boundaries are very uncertain. These outlines are quite independent of the position of the microlites, a fact indicating that it is the base alone in which the microlites lie, which has been altered molecularly, and which behaves under crossed nicols something like a crystalline aggregate. It is necessary to note, then, that the visible structure under ordinary light is replaced under crossed nicols by a previously invisible structure; and the microlites, though not absolutely vanishing from view, can only be seen with difficulty. They have only a negative influence on the light. They seem to run in among the petrosiliceous material which now, in contradistinction to the microlites, shews its inherent differences of molecular constitution by its positive effects on the light.

The rock would seem from this to be a petrosiliceous rock, with a confused devitrified base, crowded with minute microlites. The mottled or mosaic-like appearance of the base under crossed nicols seems to indicate that quartzose and felspathic minerals are separating out, though they have not done so so entirely as to be visible under simple transmitted light. The question arises, what was the destiny of the microlites; would they have been absorbed, or would they, if progress had not been arrested by solidification (as seems indicated by their yellowish colour), have become some other mineral, such as mica or hornblende?

Specimen No. $\frac{7}{766}$.—This specimen is taken from the crags above Rheetheea Tea Factory, near Lobah. Sp. gr. = 2·65. I at first overlooked this rock in the field, taking it for a quartzite, as it weathers on the surface exactly like one. A freshly broken specimen shows it to be entirely different, with a dark green ground-mass, vaguely showing flow-structure and full of angular fragments of compact, lighter tinted rocks, flesh-coloured, and sometimes pale greenish grey. It is a very beautiful rock, and undoubtedly forms a portion of the same flow as No. $\frac{7}{786}$. It appears to pass into the Lobah conglomerate by the fragments becoming more and more rounded, and the petrosiliceous matrix becoming less pronounced, or replaced by fine clastic material. (See above.)

Microscopical.—Under the 1 inch objective the rock is seen to be as much clastic as volcanic. The ground mass is of an olive green colour, showing very distinct flow structure. The fragments of other petrosiliceous rocks included are angular and of all shapes. Their intimate structure is very like that of the previously described specimen; and they probably represent caught up dust and fragments of older flows which have become brecciated. No doubt both the included fragments and the enclosing rock were practically of the same age. Quartz is also present in small grains, all of which are angular and the remains of more or less perfect crystals. There is a certain amount of black and dark brown opacite. Small cracks in the rock are lined by secondary quartz, chalcedony or "quartz grenu." Under the ¼ inch objective the ground-mass can be discerned as having a clear base like the last described rock; but it is more thickly crowded with pale green microlites, which are clustered together in irregular patches, as well as being generally disseminated through the base. These green microlites have apparently but little effect

optically, except that their density prevents so much light passing through under crossed nicols as there would otherwise be. The mosaic appearance of the base is consequently to a large extent shrouded. I could not see any, or very little polarization colour due to the microlites, as the stage was revolved, such as can be made out in the rock next to be mentioned. Doubtless the microlites in this case were just too small. The flow-structure, which is very prominent, is manifested by differences in the amount of colour and in the fineness of the bands of microlites.

Altogether, the rock exactly resembles a brecciated, devitrified rhyolite, in which a considerable quantity of fragments of other flows have become mixed or caught up.

Specimen No. $\frac{1}{787}$.—Loose block in the stream east of Saliana near Lobah and found *in situ* ½ mile N.E. of Marwara near the road to the Dewalikhal pass. Sp. gr. = 2·73. This rock links the gneissose granite of Dudatoli with the ancient rhyolites and brecciated rhyolites just described in detail. It seems to have a matrix very similar to that of the rhyolites themselves, and dispersed through it are large eyes and more or less rounded crystals of felspar, which give it a porphyritic augen structure. It has also plenty of free quartz in large irregular grains. I take the following extract from my field note-book :—"Matrix, a dull pale greenish grey, perfectly compact so far as the eye can see, save for a flow structure and faint banded appearance, dividing it into sinuous lines of paler and darker colour. The contents distributed in the matrix are a smaller set of granules of somewhat dark quartz, and small rounded eyes of felspar. Its porphyritic nature is given to it however by the presence of large eyes of felspar, rounded and oval, between which, as well as between the smaller particles, the matrix appears to have flowed. In some cases the eyes of felspar, especially the larger ones, have become cracked and partially displaced, and the matrix seems to have flowed in between the adjoining portions and so encompassed them."

Microscopical.—This rock, so far as its ground-mass is concerned, is very slightly coarser than No. $\frac{1}{768}$, the green mineral being rather more strongly represented by somewhat larger microlites. Like it, however, it is of an olive green colour, and by small differences in tint and in the density of the microlites, flowstructure is manifest among the petrosiliceous material which has found its way between the porphyritic crystals and included fragments scattered through it. Under the higher powers of the microscope the evidence of its having flowed is added to by a vaguely linear arrangement of the microlites, indicating that they had become turned more nearly parallel to the direction of flow, as they were swept on in the molten current. Of the porphyritic elements in the rock the large orthoclase crystals are the most conspicuous. They are of an opaque porcellaneous appearance under a low power, and have a very ancient look, disfigured by a corroded outline, and by the ramifying of innumerable veins of secondary quartz through them, and also by portions of the ground-mass, full of microlites, being similarly thrust in between widely open cleavage cracks at right angles to one another. The secondary quartz was introduced last of all, for it cuts through the ground-mass in the matrix and through the tongues of the same which penetrate the orthoclase. The free quartz is usually arranged in hexagonal groupings of three or more crystals, with some of their outlines fairly intact and with others corroded away and jagged, indicating that, though the quartz

had crystallized out originally, it had suffered considerably during its transit in the molten flow. In one place a portion of the compound crystal was very nearly separated from the rest by inclusions of the ground-mass along parallel cracks; which gave the nearly separated portion the aspect of being connected by threads with the remainder, and ready to part at any instant. Secondary quartz along lines of infiltration invades the crystalline quartz also. Innumerable minute cavities throng the quartz, but they are unresolved under the $\frac{1}{8}$ inch objective.

Besides porphyritic orthoclase and quartz, there are also portions of other petrosiliceous flows in rounded fragments, a few sharply marked off from the ground-mass, but mostly appearing as half fused up and amalgamated with the ground-mass. Distinct irregular clumps of opacite are present in fairly large quantities.

Under crossed nicols, as in the previous cases, no undifferentiated glassy base can be satisfactorily made out. The grey-blue mosaic indicates at once devitrification structure, which is not quite so much obscured as in the previous rock slice. The general effect is not quite so dark. The embryonic quartz and felspar appear to have gone a little further towards separating out into distinct granules. Without the crossed nicols, however, this separation is quite invisible. Under the $\frac{1}{4}$ and $\frac{1}{8}$ inch objectives the microlites of the green mineral are seen to be rather larger than in the last rock, and to have a decided effect on polarized light, so that when the nicols are crossed, the somewhat parallel microlites light up the field of the microscope with multiform coloured brush-like aggregates.

From all points of view this rock must be considered akin to No. $\frac{7}{768}$, save that it contains crystals of the "first consolidation," *viz.*, porphyritic quartz and felspar. It may therefore be called a devitrified porphyritic rhyolite. Had the rock solidified under a pressure of super-incumbent rock and cooled slowly, it seems probable that it would have resulted as a microgranulitic rock or elvan, with the porphyritic addition of quartz and orthoclase. It would be difficult, therefore, to deny it an intermediate position between the gneissose granite of Dudatoli and the purer rhyolitic lavas.

Specimen No. $\frac{7}{768}$.—This is from the same locality as No. $\frac{7}{765}$. Sp. gr.=3·03. It is undoubtedly a vesicular variety of the purer rhyolite. In the hand it is pale whitey green in colour, splitting with some difficulty along the direction of original flow. Under the microscope its only peculiarity, as distinguished from No. $\frac{7}{765}$, is the large number of gas-pores, which are filled with reddish iron oxide. These account for its high specific gravity; for another fragment taken from the same piece of rock, but less full of amygdules, has a specific gravity of only 2·66.

Specimen No. $\frac{7}{769}$.—Sp. gr.=2·63. This rock is not from the locality of Lobah, but from the stream-head running west to Peera from the Dobri ridge. It is mentioned here because it links the thoroughly brecciated and clastic forms of the rhyolite with the amorphous compact varieties. It is pale grey or whitey green in colour, showing a distinctly banded structure, which has in places become interrupted by one of the bands becoming distorted and brecciated, and by the interbanding of minute rounded quartz grains, suggestive of a fragmental origin. This structure clearly evinces that partial cooling had been followed by further flowing of the semi-solidified mass.

These few examples are sufficiently typical of the acid lavas and their allied forms, as developed in the neighbourhood of Lobah. Others from localities N.W.

of the Dudatoli massif will be described in due course, and also some allied compact red porphyrites, or ancient rocks, of a less acidic character, found near Charmarguri trigonometrical station. There also remain to be considered the basic lavas which seem to replace or overlie the acidic lavas at some parts of the margin of the Dudatoli area. Though far more abundant than the ancient rhyolites, I have deferred their examination until later, because their connection with the gneissose granite seems to be inadmissible. It is indeed difficult to account for the plutonic representatives of these lavas; nevertheless, until the district is completely mapped, it is unsafe to say that they have no such representatives.

I will conclude these petrological notes by a reference to the differences in metamorphism between the old schistose series west of the great fault near Lobah, and the very slightly schistose rocks which lie to the east of it. The garnets, and well developed plates of mica, which characterize the old schistose series end abruptly at the fault. Now, as was shewn in my last paper, the production of garnets in the schist and the appearance of the Dudatoli gneissose granite must have been contemporaneous, and probably inter-dependent. It therefore follows that the argument for the great age of the gneissose granite previously founded on other and more general grounds, is now buttressed by this additional fact concerning the distribution of the contemporary metamorphism.

The Iron Industry *of the* Western Portion *of the* District of Raipur, *by* PRAMATHA NATH BÔSE, B.Sc. (Lond.), F.G.S, *Deputy Superintendent, Geological Survey of India.*

Literature.—The notice taken in the article on "Raipur" in the *Central Provinces* Gazetteer (published 1870) of the iron-ores of the district is very poor. Only two localities are mentioned, and not a word is said about the mode of occurrence, the extent, or the working of the ore. It is no wonder, therefore, that Mr. Ball, the accomplished writer of the "Economic Geology of India," should have summarily disposed of the iron-ores of the Raipur district by saying, "Little or nothing is recorded as to the iron-ores of this district."

In Appendix III, G. (Mines and Quarries) of the last number of the Central Provinces Administration Report (1885-86), half-a-dozen iron-ore localities are mentioned as occurring in the district of Raipur, *viz.*, "Kondkasar, Bhindo, Lahora, Dalli, Sambarsingha, and Magarkund." The history of several of these names is not without interest. In the Administration Report for 1868-69 the names given are "Condkusar, Bhindo and Lohara, Dallee, and Muggurkund." Two years later we find "Lohara" separated from "Bhindo" and joined on to Dallee as "Lohara-Dullee;" it was subsequently again disjoined from Dallee, and transformed into "Lahora." But I know of no place of that name in the Raipur district where iron-ores occur.[1] "Lohara-Dalli" would be more intelligible, for the hill of Dalli,

[1] There is a Lohara hill in the Chanda district where iron-ores of good quality are known to occur.

which is full of iron-ores, one variety being the richest as yet found in India, being situated in the Daundi-Lohárá zamindári. "Bhindo" and "Sambarsingha," I have not yet been able to identify.

2. *Extent of the ores.*—The number of places where iron-ores and smelting furnaces exist is much larger than that given in the statistical tables cited above. Of the localities noted by these, Magarkund is the only one where the ores are still worked, the furnaces at Kondkasar, Dalli, &c., having been given up for some time past. On the other hand, as will be seen from the following list, there are numerous places not mentioned in the statistical tables where I saw furnaces at work (season 1882-83.) The number of these is very variable and must be taken as approximate. The *Agarias* who work them are a very unsettled people, leaving a place as soon as the neighbouring jungle fails to satisfy their requirements, or the zamindár enhances the duty levied on their furnaces.

I. GANDÁI ZAMINDÁRI.

Magarkund.—Here the ore worked is red hæmatite occurring as nodules in alluvium a mile and a half north-east of the village at the foot of a hill of red ferruginous Chilpi (? transition) sandstone. The ore is evidently derived from the latter. I saw eight furnaces at work in the village.

II. THÁKURTOLA ZAMINDÁRI.

(*a*) *Chutrala* (*deserted*).—The ore is like that of Magarkund in extent and mode of occurrence. It is no longer worked.[1]

(*b*) *Kumi.*—Here the ore is of considerable extent and occurs in lateritic beds overlying black basaltic rocks which appear to be intrusive in the Chilpis.

(*c*) *Basantapur* (not marked on map).—A village near Kumi, several smelting furnaces are at work here. Ore as at Kumi.

III. NÁNDGÁON FEUDATORY STATE.

Lateritic ore abundant over an area of eight square miles, at *Bháwá*, *Jurlákhár* and *Chuhuri* (depopulated), now worked only at *Jurlakhar*,[2] where I saw four active furnaces.

IV. KHAIRÁGAR FEUDATORY STATE.

In the western portion of this state north of Dongargar is a jungle-clad hilly country, which is full of iron-ores. These are very largely worked, there being furnaces at *Borlá*, *Katulkassa*, *Banjár* (not marked on map), &c., probably aggregating twenty in number. The ores mostly occur in soil covering basaltic rocks which appear to be intrusions in the Chilpis; but rich hæmatite, among beds of red sandstone, is also met with.

V. WORÁRBAND ZAMINDÁRI.

West of *Worár* a mile south of the great eastern road from Nagpur to Raipur, I found iron-ore in lateritic deposits covering beds of hard, red, nearly flat sandstone (Chandarpur). The country is poorly wooded; and, as far as I could ascertain, it has never been utilised.

[1] Last season furnaces were working at Murwabhat, 3 miles south-east of Chutrala.

[2] From information last season (1886-87) I learn that the village is now deserted.

VI. DÁUNDI-LOHÁRÁ ZAMINDÁRI.

The richest and most extensive ores of the district are to be found in this zamindári. Furnaces exist at *Killákord*, *Ungárd*, *Hirkápár*, &c. The hill of Dalli, for about 7 miles of its length, is full of good hæmatite, which is developed in hard, red, rather thin bedded ferruginous Chilpi sandstone. The villages of Dalli and Kondekassa once possessed a very large number of furnaces, but they have been given up, owing, I heard, to the Zamindár of Lohara having raised the duty levied on iron furnaces.

3. *Analyses.*—Four specimens of the ores brought by me were analysed by Mr. E. J. Jones, of the Geological Survey, with the following result:—

	Percentage of iron.
1. Dalli	72·92
2. Do.	67·41
3. Chutrála	63·82
4. Worarband	53·24

4. The first variety of the Dalli ore appears to be the best that has as yet been found in this country, as will be seen from the following comparison:—

	Dalli. (Raipur.)	Lohara hill.[1] (Chanda.)	Agaria.[2] (Jabalpur.)	Sanlow.[3] (Rájputuná.)	Dechaun.[4] (Kumáon.)
Percentage of iron	72·92	69·208	68·28	66·00	55·13

5. *Fuel and Water Supply.*—All the places mentioned above, except Magarkund and Worarband, are situated in fairly wooded forests; and those near Dalli, especially to the west and south-west of it, are exceptionally good, so much so that a charcoal furnace on a large scale could possibly be maintained here to advantage. The fuel used for reduction of ore in the furnace is obtained from *Dhaora*, *Salai* and similar trees of comparatively little economic importance, teak and other timber-yielding trees being not allowed to be cut down for the purpose. For refining, bamboo charcoal is employed.

Of all the places tabulated above, Dalli is most advantageously situated as regards supply of water, several springs in the neighbourhood yielding it in a very pure form. Mr. E. J. Jones of the Geological Survey, who kindly analysed a sample of the spring water, detected the merest traces only of lime and chloride in it.

6. *Flux.*—Flux is never used in the furnaces which I saw at work. The Raipur (Lower Vindhyan?) limestone is usually not far off from the iron-ore localities. As regards Dalli, the nearest outcrop of it is at a distance of 20 miles. One specimen of the stone, analysed by Mr. Hiralal, of the Geological Survey, gave the following result:—

Carbonate of lime	83·50
" " magnesia	2·00
Oxide of iron and alumina	0·90
Insolubles	13·60
	100·00

[1] "Manual of the Geology of India," Vol. III, p. 388.
[2] Records, G. S. I., XVI, p. 97.
[3] Manual, III, p. 395.
[4] Ditto p. 409.

7. *Mode of working*, &c.—The furnaces are of a primitive character, not unlike those described at p. 380 of the "Manual of the Geology of India," pt. III. The ore selected is almost invariably the softest, though not always the best, available. The metal turned out by the furnace is refined in an open hearth, and is made into bars called *chuls*, which are sold to blacksmiths at an average rate of five annas per *chul*. The outturn per day from each furnace, supposing eight persons to be employed for preparing and bringing fuel and ore, and for working at the bellows, would be four *chuls*, selling at one rupee four annas.[1] Fixing the wages of work-people at two annas per head, this leaves a margin of four annas for the proprietor. The duty on the furnace has to be paid from this sum, and it may be as low as one rupee, and as high as seven rupees per annum. This, however, is inclusive of all dues on account of trees cut down for charcoal. As the only expensive portion of the apparatus employed is the bellows, which costs from three to four rupees, and as the proprietor's supply of labourers is usually drawn from his own family, he being one of them, iron-smelting is considered a fairly profitable industry where fuel is abundant, and the duty on the furnace not too high.

The furnaces are worked by a class of Gonds who style themselves *Agariás* or *Pardháns*. They almost invariably speak the Gondi language, which their brethren of the plains have quite forgotten, and would not scruple to eat cow, buffalo, &c., which the latter, who aspire to the title of Hindus, would never touch. Iron-smelting must be a very old industry with the Gonds. Their traditions ascribe their first settlement in *Káchikopá Lahugarh*, or the "Iron valley in the Red Hills;" and the only metal for which they appear to have a name in their language is iron.

Notes on Upper Burma, *by* E. J. JONES, A.R.S.M., *Geological Survey of India* (with 2 maps).

1. The Chindwin Valley.
2. The Panlaung Coal-field.
3. Two Coal Localities in the Shan Hills.
4. Lignite at Thigyit near Nyaungwe.
5. Metalliferous Mines in the Shan Hills.

1.—THE CHINDWIN VALLEY.

Recent and alluvial deposits.

The strata exhibited in the Chindwin river at Monywa, the lowest point which I visited, consist of recent sand, resting on a ferruginous conglomerate containing fragments of the well known fossil wood[2] so widely distributed in Burma. I found this fossil wood at almost the highest point to which I travelled on the Chindwin (the neighbourhood of

[1] From the manner in which the operations are performed, it is impossible to form anything like a correct estimate of either the outturn or of the working expenses.

[2] Derived from the "fossil wood group," of Mr. Theobald. See Memoirs, G. S. I., X, p. 247.

the mouth of the Kalé creek), and as far east as a short distance from the base of the Shan Hills; while according to Mr. Theobald it is of very wide-spread occurrence in Lower Burma.

At Alon, 5 miles up the river above Monywa, the same conglomerate is seen dipping slightly towards the east.

Tertiary.

Above Alon the banks are low and sandy for some distance, but a few miles above the station, a ridge of sandstone, which, from the launch in which I was travelling, appeared horizontal, but which probably dips, as do the strata everywhere in this part of the country, to the east, is seen running across the river from east to west and forming a low cliff on each bank.

Above this point the right bank becomes less sandy and higher, while the left bank remains low and chiefly composed of sand. Another ridge of sandstone runs across just by Yathit.

Above this point similar sandstone frequently appears in both banks, though at the time I visited the locality the channel was frequently separated from the actual river bank by wide stretches of sand-bank, between which the little water that was left in the river flowed.

Some miles below Kani the banks become quite low and sandy again, but at Kani there is a precipitous cliff, just above the village, formed by a small range of hills running nearly north-south, which here crosses the river.

At the bottom of this cliff, which is about 200 feet high, there are 20 feet of coarse ferruginous conglomeratic sandstone, above which the sandstone becomes much finer and lighter coloured, being of a light buff, though bands of the darker coloured ferruginous sandstone are to be seen at intervals all the way up.

Above Kani the banks gradually become low again till, at about 17 miles below Maukadau, the river passes through a much higher range of sandstone hills. Above this the river becomes wide and much spread out, and blocked with sand-banks, though low hills are always to be seen at no great distance from the river.

Above Mingin soft sandstones are seen on the right bank dipping to the east under the river; the left bank is fairly flat with an occasional small outcrop of the sandstone.

Cretaceous?

At the junction of the Kalé creek (or Myit-tha) a fine-grained greenish yellow sandstone, harder at and near the weathered surface than inside and containing courses of a harder sandstone, is exposed dipping to E.15°S. at 30°. The harder courses are due to infiltrated silica and ferruginous matter. This sandstone also contains in parts ferruginous nodules and bands of a somewhat coarser texture.

Position of the field.

The Kalé Coal-field.—This is only a small portion of what promises to be a much larger field. It owes its name to the fact of some coal having been found and worked to some extent in the so-called Kalé creek (the Myit-tha), which flows into the Chindwin at the village known as Kalewa (Lat. 23° 4′ N., Long. 94° 25′ E.), situated on the right bank of the Chindwin between Mingin and Kindat.

Other coal seams on the Chindwin.

I was informed by those who had the opportunity of observing the neighbouring country that this is by no means the only tributary of the Chindwin in which coal occurs, but that it is to be found in almost, if not quite, all the streams flowing in on the right

bank below the Kalé creek, and to the north of this point as far as Tamu. Coal was also reported by Captain Stevens through the Political Agent, Manipur, in 1886 to occur in large quantities in the Kubo valley, though Captain Stevens did not think it would ever be able to compete with the Kalé coal.

Coal in Kubo valley.

The only coal locality I visited was that on the Kalé creek. The coal is here found out-cropping in the right bank of the stream about $2\frac{1}{2}$ to 3 miles above its junction with the main river, and just below the villages of Thitcho on the left bank, and Chau-oung on the right bank. About a $\frac{1}{4}$ mile below Chau-oung a small stream runs into the creek from the south, immediately below which the main seam of coal is exposed.

Position of the coal outcrops.

The whole section as seen is as follows in descending order, the dip being to the east at 45° :—

Strata.	Thickness.		Remarks.	
	Ft.	In.		
1.—Sandstone	5	0	Only 5 feet are exposed, the upper portion being concealed by alluvial clay.	
2.—Carbonaceous clay, with bright jetty bands of coaly matter.	2	0		
3.—Fine bedded shales . . .	20	0		
4.—Hard, calcareous, shaly sandstone containing fragments of fossil plants.	2	0	This is however only a local bed, as it thins out and disappears within 20 feet.	
5.—Shale containing concretionary masses resembling No. 4.	50	0		
6.—Coaly matter	2	0	This is the maximum thickness; it varies from 2 ft. to 6 in. and back to 2 ft. within a few feet.	
7.—Carbonaceous sandy shales . .	10	0		
8.—Sandy shales	20	0		
9.—Clayey shales	30	0	Contains courses of exfoliating ferruginous lumps in the undecomposed centre of which are fragmentary plant remains by the talus from a small stream.	
Here the section is concealed for 150 feet.				
10.—Hard band of a heavy stone similar to No. 4.	1	0		
11.—Shales	30	0		
The section is here again concealed			for a few feet.	
12.—Very much broken and partly decomposed blue shale.	5	0		Nos. 12-16 were exposed in the quarry.
13.—*Good Coal*	10	0		
14.—Inferior coaly shale . . .	1	9	Useless.	
15.—Brown clayey shale, with strings of coaly matter.	1	7	7 feet is all that is seen of this grey shale, 5 feet are seen in the coal quarry and 2 feet below the quarry; the concealed interval is at most 4 feet.	
16.—Grey shale	7	0		
Carried over .	197	4		

Strata.	Thickness.		Remarks.
	Ft.	In.	
Brought forward .	197	4	
17.—Coaly matter	0	9	
18.—Clayey shale	1	0	
19.—{Coaly matter . . Ft. 0 In. 5; Clay shale . . . 0 7; *Coal* . . . 1 0}	2	0	The clay shale is a mere local bed which thins out in a few feet.
20.—Shale, with coaly strings . .	12	0	
21.—Carbonaceous papyraceous shale .	3	0	
22.—Yellowish shales . . .	11	0	
23.—Sandstone	4	0	
24.—Shale	1	0	
25.—Sandstone	1	0	
26.—Shale	5	0	
27.—Carbonaceous shale . . .	1	0	
28.—Yellowish shale	4	10	
29.—Coaly matter	4	7	
30.—Loose shale	2	6	
31.—Good bituminous bright coal .	0	6	
32.—Carbonaceous shale . . .	0	10	
33.—Yellowish shale	21	0	
34.—Sandstone	1	0	
35.—Sandy shale, with bands of sandstone.	10	0	
36.—Soft sandstone, with irregular courses of harder sandstone.	30	0	
TOTAL .	314	4	

This sandstone (No. 36) forms an escarpment on the east bank of the small stream mentioned above as flowing into the creek just above the coal.

To the west of this stream nothing is seen except the alluvial soil of the bank, till some courses of a hard sandstone are seen just below Chau-oung (about quarter of a mile up the river).

Below the sandstone is a 2-in. seam of bright bituminous *coal* resting on shale, beyond which alluvial soil again covers all.

To the south of this, on the opposite (left) bank of the river, and just above the village of Thitcho, a 2-ft. seam of bright *coal* is exposed, with broken shale above it and grey shale below. The dip here is also to east at 45°.

Above this in the series of rocks (*i.e.*, down the river) are about 39 feet of fissile sandstone and shale, then 6 inches of coal and 1 foot 6 inches of grey shale, beyond which the section is concealed on this side of the river. It is probable that one of these seams corresponds to the 2-in. seam seen on the other side.

Further small seams of coal in tributary streams.

Going up the small stream running into the river just above the 10-ft. seam of coal, nothing is seen for the first mile but fine-grained sandstone (sometimes fissile and much broken) and blue, grey, and yellow shales of the same character as those exposed in the main section. About one mile up on the right bank, there is a band of papyraceous coaly shale varying from 4 to 6 inches in thickness, and covered by grey shale streaked with black and containing some threads of bright bituminous coal. This must be some hundreds of feet below the seams exposed in the creek, as from this point the stream runs chiefly east and somewhat north, to its junction with the creek, the dip remaining 45° E. all the way.

About half a mile further up, on the left bank, is a great mass of grey and somewhat carbonaceous shales containing a 10-in. seam of *coal*, covered with grey shale and having carbonaceous shale below. The dip here is to E. 10°N. at 35°. About 20 feet further up the stream (*i.e.*, below in the series of beds) is another 2-in. seam of *coal*, and 100 feet further on a seam 1 foot 4 inches thick of *coal* dipping to east at 45°. These coals are all of the same character, being bright bituminous coals with cuboidal fracture, but containing layers of dull coal. About 50 feet further on, below the series of shales and coal, is some very hard slightly calcareous sandstone, containing impressions of fossil leaves, and in which I also found the internal cast of a gasteropod shell.

There is another small stream flowing into the creek on the left bank above Thitcho village, in which a small seam of *coal* (1 foot 2 inches) is seen, with clayey shale both above and below it. The dip here is only 35° to E. About a quarter mile further up is another 1-ft. seam of *coal*. These are both of the same bright bituminous and jointed character.

Up the main creek nothing is seen, as far as I went, of any coal; but there must be some further up, as I found small fragments of coal on the sandbanks in the bed of the river.

Down the river also I saw no signs of coal, the greater part of the rocks, where exposed, being hard sandstone.

Number of the seams.

We have thus within an area of about one square mile ten distinct seams of coal, all, except one, of which are however useless. I was also informed subsequently to my visit of another exposure at some distance from the river on the left bank. There are probably numerous other

small seams in the neighbourhood, though not in such a favourable position for working as the 10-ft. seam, even if they are of sufficient thickness.

Quality and age of the coal.

The coal appears to be of a fair quality, the great drawback being its friable nature. It contains the numerous small veins and pockets of fossil resin noticed in some of the cretaceous coals of Assam, and the Lenya river coal of Tenasserim, which is a good sign as cretaceous coal is more likely to extend to a distance than the uncertain seams of tertiary age. No pyrites can be detected by optical examination.

Value of the seam.

The position is very favourable for working, being in direct communication with the Chindwin. The best and simplest means of carriage would be by water: the coal would have to be loaded into flats at the pit's mouth, and the navigation down stream would probably not present any great difficulties. Another thing on which the value of the seam depends to a very great extent, is its lateral extension and the depth to which it reaches. In order to test this it will be necessary to put down experimental borings, and I have recommended that this should be done as soon as possible.

Position of the mine.

In the borings, it must be remembered that, owing to the high dip of the seam, the coal will appear to be thicker than it really is. Should they give equally favourable results on both sides of the river, I should recommend the mining, at any rate at starting, to be carried on on the left bank, as the ground is there much flatter, with a small plain between the river and the hills, whereas on the right bank the hills come right down to the river. These preliminary trials should be put down by Government in order to see whether the coal extends to any distance.

Stoppage of workings.

The workings which were being carried on at the time of my visit have since been stopped by order, as they were not only ruining the future prospects of the place as a mine, but also, owing to their dangerous nature and the consequent fear of the villagers in digging the coal, there might be great difficulty in procuring labour hereafter.

These workings consisted of a quarry, which was being driven in along the strike in a southerly direction from the river. There are about 20 feet of a coarse gravel (containing boulders 3 feet to 4 feet in diameter) above the coal. The workmen removed the upper 7 or 8 feet of the coal, leaving the upper gravel unsupported, which consequently fell down after the coal had been removed for some distance; indeed on one occasion one of the workmen is said to have been crushed to death.

If there was any one with even a slight practical knowledge of the class of work, the danger could be easily avoided by temporary supports and breaking down the heavy stones before they became loose; but even then the place would be ruined for a mine, as the quarry would subsequently become a means of entry for water and necessitate expensive pumping machinery. On this account I recommended that work should be stopped before any more damage was done.

If coal is, however, required for present use it might be obtained by driving an inclined tunnel on the coal from the top of the bank of the stream to the west, which would reach the coal in 20 to 30 yards, and need not incline downward more than 10°. It should be started where the clay forming the bank begins to cover up the sandstone at the corner where the stream, after running east, turns abruptly north

before running into the Kalé creek; and it should be driven due east: or the tunnel might be started at any point between this and a line drawn due south from the closed workings; in which case it would be shorter, but the inclination would have to be greater.

Specimens of the coal which I sent for assay in Calcutta were unfortunately burnt on the way, so that I am unable at present to give any opinion as to the value of the fuel, as compared with other known coals; but it burns well, and the engineers and serangs on the steamers using it praise it very highly.

Means of transit.

As regards the means of transit, I should decidedly recommend water carriage, as it is ready to hand. I have not been able to see the creek during the rains, but it would probably be navigable for vessels of light draft during all seasons of the year, and the coal could be floated down to the Chindwin in light draft barges.

Supply of labour.

From enquiries I made on the spot, and from the information supplied by Captain Raikes (the Deputy Commissioner), it appears that the supply of labour would be quite equal to the demand when once the people had got accustomed to the class of work, but at first, at any rate, a certain proportion of skilled workmen would have to be imported from India, as the people are quite unused to the style of work. After they had learned the proper way of using ordinary mining tools, &c., this imported labour could be to a great extent dispensed with. At present the only tool they use is a kind of rough spud, such as they use for agricultural purposes.

An efficient European staff would also have to be provided, on whom the success of the enterprise would in a great measure depend.

Disposition by the inhabitants.

The attitude of the surrounding people at the time of my visit was quite friendly and obliging. But, owing to their primitive state, their behaviour would probably depend to a great extent on the disposition of, and the orders or hints received from, the Sawbwa.

Age of coal rocks.

The rocks in which the coal occurs appear, from the presence of fossil resin, and thus by analogy with the cretaceous coal of Assam, which also contains a similar resinous substance, which is characteristic of the cretaceous coals of that region, to be of cretaceous age.[1] The sandstones exposed lower down the creek and in the Chindwin are of lower tertiary, or more probably partly tertiary and partly upper cretaceous age; but I was unable to see enough of the country to determine their age with any degree of certainty.

Opposite to Monywa, at a distance of about 3 miles to the west of the river, there is a hill formed of petrosiliceous volcanic rocks. In this hill,[2] which is known as the Letpadaung Taung, there are the remains of a copper mine, which was formerly worked by Oo Chaung, the younger brother of the Kinwoon Mingyi. Whether he ever obtained any large quantity of copper I was unable to find out, but I should think it very unlikely that the output was at all considerable, as the only traces of copper now extant consist of a few stains of green carbonate. The presence of the volcanic rocks is, however, interesting as forming a further link in the volcanic chain run-

[1] Records, G. S. I., XVI, p. 165.

[2] My attention was called to this locality by Mr. D. Ross, Assistant Commissioner, Alon, who visited the spot with me.

ning north through Narkondam and the extinct volcano of Paopadaung, visited many years ago by Mr. W. T. Blanford[1] who pointed out that Paopa was the continuation to the north of the great eastern line of volcanic outbursts running through the Eastern Archipelago.

2.—THE PANLAUNG COAL FIELD.[2]

The Panlaung river takes its rise near Singulèbyin, and flows northwards by a tortuous course till it eventually joins the Myitngè river, just before its junction with the Irrawaddy near Ava.

Position of the coal field.

The Panlaung coal field is situated on the right bank of the river, near its junction with the Myittha (which flows past Pyinyaung, the first post out of Hlaingdet, on the Shan Hill road). On the map of Upper Burma (1 inch = 16 miles), second edition, published by the Surveyor-General of India, the coal region is not marked as such, but it is situated in the neighbourhood of the spot marked Taungnga village (Lat. 21° 3′ N., Long. 96° 24′ E.), nearly opposite the village of Pachaung (or Petkyaung).

Impossibility of exploring the country thoroughly in its present state.

In the present state of the country it was impossible to make more than a very superficial examination of the coal, as no supplies were obtainable except from Hlaingdet, a distance of 30 to 40 miles by road, and coolies were unwilling to visit that part of the country. The region is very wild and there are no inhabited villages, all the inhabitants having retired from fear of dacoits, who have harassed them in former years, to the jungles, where they subsist upon such jungle roots, fruits, and other food as they can procure. They were, however, at the time of my visit, recovering from their state of alarm, as the country is now quieter than it has been for years: in some parts they have sown paddy; and the Thugyi of Minpalaung or Membaloung told me that he proposed shortly to rebuild his village and live there again. When the country has settled down, it would be possible to make a closer examination of the coal, though its unhealthiness would always make this a difficult matter; while at least a whole working season would be necessary for the purpose.

Various outcrops of coal.

The coal is exposed in the beds of the streams running into the Panlaung on the right bank, and in the hillsides to the east of the river. I was only able to visit the more accessible of the groups of outcrops, of which the following is a list:—

The Pagamyaungchaung group.
The Mithuiçhetkyauk group.
The Ingôndaung group.
The Thabyetaungdan group.
The Chobinmyaungchaung group.
The Chobinmyaungmachaung group.
The Chakimyaungchaung group.
The Thaikthaw group.
The Kyatthaungdaung group.
The Kyaulimyaungchaung group.
The Ludwin group.

[1] Journal, A. S. B., XXXI, p. 215.

[2] See map 2.

I travelled from Hlaingdet by Pyinyaung and Taungkubyin to Sôngyi, at the junction of the Myittha and Panlaung rivers. Sôngyi is about 15 miles from Pyinyaung, and the road, though bad, is capable of improvement. From Sôngyi I visited the Pagamyaungchaung and the Mithuichetkyauk. The other localities I visited from Minpalaung.

Outcrops visited.

The Pagamyaungchaung runs into the Panlaung river at a distance of from 4 to 5 miles below Sôngyi. In this stream, which was nearly dry at the time I visited it, there are several exposures of coal.

Pagamyaungchaung outcrops.

The greater part of the rocks seen by following the stream up from its junction with the Panlaung consists of granular limestone, shales, and calcareous conglomerates:—

I.[1]—About 1½ miles up the stream bed the first signs of coal are seen in the form of a bed of dark shales, dipping to the S. W. at 75°, and containing a 2-ft. thick pocket of glistening and much fractured coal, which thins out in a distance of 2 feet to a thickness of 4 inches.

II.—One hundred yards further up the stream, here flowing from N. to S., is another bed of shales, with coal dipping to S. W. at 60°; the following section being exposed:—

	Ft.	In.
1. Granular limestone (thickness not seen)	...	...
2. *Coal*	2	0
3. Carbonaceous shale	9	0
4. *Coal*	2	0
5. Red and white shale	3	0
6. Limestone (not gone through)	...	...
TOTAL	16	0

(Coal 4 ft.)

The coal has a greasy feel, and readily breaks up into small fragments, being traversed by irregular lines of fracture throughout the mass, but some of it would make a good fuel.

Some of the shales contain obscure and indistinct plant impressions.

Further up the stream there are several more smaller seams exposed in the same manner, but none exceeding 2 feet in thickness, and all with the same high dip and unsatisfactory appearance.

The Mithuichetkyauk locality is on a hill about three miles from Sôngyi, on the road to Singulèbyin. The hill overlooks the Panlaung river, and is on the left or west bank and therefore in British territory.

Mithuichetkyauk outcrops.

There are here six exposures displayed on the hillsides, and remains of the old workings are to be seen.

[1] The Roman numerals refer to the Table of Outcrops (see page 187).

III.—In the first exposure the section seen is as follows, the dip being to S. W. at 72°:

Section (a).

	Ft.	In.
1. Sandstone (total thickness not seen)	...	...
2. Dark shale	.	.
3. *Coal*	1	6
4. Shale	2	0
5. Carbonaceous shale	4	0
TOTAL	7	6

(Coal 1 ft. 6 in.)

Signs of this coal are seen in two places along the strike, and 100 feet in the same direction we have the following section:—

Section (b).

	Ft.	In.
1. Sandstone (thickness not seen)	...	...
2. Shale (red and white, and much foliated)	4	0
3. *Coal*	1	6
4. Muddy, clayey shale	0	3
5. *Coal*	1	9
6. Red shale (bottom not seen)	...	...
TOTAL	7	6

(Coal 3 ft.)

This being in the direction of the strike, probably represents to some extent the section (*a*).

Two hundred feet to the dip two more exposures of coal are seen, one only 6 inches in thickness and the other but little better. The following section can be made out at the second exposure:—

	Ft.	In.
1. Shale containing ferruginous nodules (whole thickness not seen).	...	...
2. *Coal*	0	4
3. Dark shale	3	0
4. *Coal*	1	0
5. Red and white clayey shale (whole thickness not seen)	...	...
TOTAL	4	4

(Coal 1 ft. 4 in.)

In No. 4 the *coal* thins out, in a distance of 2 feet, to a mere string, but again increases in thickness to 2 inches further on.

The Ingondaung hill is near Minpalaung, about 2 miles in a south-westerly direction. The path from Minpalaung crosses the Chuadamyaung (or Ye-e) Chaung.

Ingondaung outcrops.

IV.—On the side of the hill towards Minpalaung (N. E.) eight inches of coal are to be seen. The ground has fallen in and concealed the section to a great extent, but the dip is to S.70°W. at 70°, and there is a red clay both above and

below the coal, the upper clay being somewhat shaly. This coal is said to be 2½ cubits thick at a depth of 5 cubits.

V.—A few yards further up the hill, *i.e.*, to S. W., there is another seam dipping S. W. at 40° and only 1 foot 6 inches in thickness; this is also said to increase in thickness lower down, but the thickness is probably to a great extent made up of dark shale. Below the coal there is a brownish shale containing fragmentary plant remains, while above the coal is a white clay, spotted with red.

VI.—A short distance round the hill, towards the S. E. from outcrop No. V, there is a perpendicular band of silicified sandstone, varying in thickness from 2 to 4 inches and running N. W. to S. E. Against this, on the N. E. side, is a soft sandstone, while against the S. W. face is the coal.

The coal is perpendicular, with the same strike as the band of silicified sandstone. The section is exposed in two places, 15 feet apart; in one of the two places only a portion of the section can be seen, as the bank has fallen in and concealed the remainder, but the siliceous band and finely jointed shales give points from which they can be compared.

Sections.

1. Finely and irregularly jointed dark grey shales, common to both (*a*) and (*b*).

	(*a*)	Ft.	In.		(*b*)	Ft.	In.
2	1. Brown clay	0	1	15 feet interval.	1. *Coal*	1	6
	2. *Coal*	0	3		2. Coaly matter	0	1
	3. Clay, with coaly matter	0	5		3. *Coal*	0	3
	4. *Coal*	0	5				
	5. Clay, with coaly matter	0	7				
	6. Concealed; said to consist of *coal*	5	3				
	TOTAL	7	0		TOTAL	1	10

3 Band of siliceous sandstone common to both (*a*) and (*b*).

Here we have evidence of the extreme irregularity of these beds, for what is in one place 7 feet, with 8 inches (or 5 feet 11 inches according to report) of coal, is reduced, at a distance of 15 feet, to 1 foot 10 inches, with 1 foot 9 inches of coal.

The coal is also much broken and very finely jointed.

VII.—About quarter mile to S. E. of outcrop No. VI there is another outcrop striking north-south, and also perpendicular at the eastern end of the section, while at the western end the dip is to S. W. at 80°:—

Section..

		Ft.	In.
W.	1. Shale, finely jointed, black (thickness not seen)	...	...
	2. *Coal*	1	6
	3. Shale (same as No. 1)	5	0
	4. *Coal*	0	6
	5. Shale (same as Nos. 1 and 3)	1	0
E.	6. Coal (much crushed)	0	6
	TOTAL	8	6

(Coal 3 ft.)

This coal is said to burn like oak, while the others burn like jungle-wood. This section is a good example of the extremely disturbed condition of the beds, for we have a difference of 45° in the direction, and of 10° in the amount of dip, in a thickness of 8 feet 6 inches.

Thabyetaungdan outcrops.

VIII.—About one mile from No. VII, on a portion of the hill known as the Thabyetaungdan, there is an outcrop containing 7 feet 6 inches of coal at the thickest portion and divided into two layers by 5 feet of clay and shale. The dip is here 60° to W. 20°N.

Section.

	Ft.	In.
1. Surface soil	...	...
2. *Coal*	2	0
3. Red and white clay	2	0
4. Usual jointed shale	3	0
5. *Coal*	5	6
6. Shale (not gone through)	..	...
TOTAL	12	6

(Coal 7 ft 6 in.)

This seam is seen again a few yards along the strike to N.20°W., but here only 4 feet of coal are to be seen. This coal is of the same quality as the rest, and there appears to be the same irregularity of thickness; and, although the dip at this point is not so high as in other parts, no reliance can be placed on this where there is so much disturbance among the rocks. In the immediate neighbourhood there are signs of numerous small excavations where the coal was formerly dug.

This is, however, the most promising of all the outcrops I saw; and it is here, if anywhere, that I should recommend explorations to be carried out, though I very much doubt their being successful. Owing to the high dip, 60°, it would be necessary to explore by driving an inclined shaft in the coal which would show whether it remains constant in thickness and quality.

IX.—Close to No. VIII there is another locality, which is chiefly interesting on account of the occurrence of fairly perfect fossil plant remains, which appear to be of tertiary age. This was the only place in which I found fossils in anything but a very fragmentary condition: they occur in a bed of clayey shale on the south side o the coal, which is here again perpendicular.

Section.

	Ft.	In.
1. Clayey shale	4	0
2. *Coal*	0	2
3. Shale	0	2
4. *Coal*	2	0
5. Earthy shale	0	2
6. *Coal*	1	0
7. Shale	0	6
8. Inferior shaly coal	1	0
9. Shale (total thickness not seen)	...	...
TOTAL	9	0

(Coal 3 feet 2 inches.)

Another outcrop containing coal occurs on the Thabyetaungdan, but it is very intimately mixed with a clayey shale, there being about 6 feet of coal and clayey shale in alternating bands of about 6 inches in each.

There are said to be many other outcrops of coal on the Thabyetaungdan, but they are probably inferior to those I saw, which were the ones formerly worked, for which purpose the thickest seams would naturally be selected.

Chobinmyaungchaung outcrops.

X. In the Chobinmyaungchaung, which is a small stream running into the Panlaung river, the following section is seen:—

	Ft.	In.	
1. *Coal*	1	6	Dip S. 40° W. 90°
2. Shale, containing a pocket of coal 6 feet long by 6 inches thick	3	0	
3. Nodular ferruginous clay	0	3	
4. Shale	0	3	
5. *Coal*	1	0	
6. Dark, jointed shale	2	2	
7. Hardened clay band	2	8	
8. Dark shale (same as No. 6)	1	4	
9. Hardened clay band	0	1 to 2 inches.	
10. Shale (same as No. 6)	5	0	
11. Clay band (same as No. 7)	1	6	
12. Shale (same as No. 6)	8	0	
13. Clay band (same as No. 7)	0	5	
14. Shale (same as No. 6)	4	0	
15. *Coal*	2	0	
16. Shale (same as No. 6)	3	0	
17. Clay band (same as No. 7)	0	4	
18. Shale containing four hard bands	8	0	
19. Shale, with streaks of coaly matter	1	0	
20. Shale (same as No. 6)	3	0	
21. Clay band (same as No. 7)	2	0	
22. Light coloured sandy shale	3	6	
23. Hard clay band (same as No. 7)	12	0	Dip, S. 30° W. 90°
TOTAL	66	0	

(Coal 4 feet 6 inches.)

The direction of the strike here alters 10° in a thickness of 66 feet. There is only a total thickness of coal of 4-ft. 6-in. in three bands. The continuation of the section was formerly exposed lower down the stream and coal worked there, but the bank has now fallen in and concealed the exposure.

XI.—In the Chobinmyaungmachaung, a small stream which runs into the Chobinmyaungchaung, there is a mass of the usual jointed black shales containing several pockets of very shaly coal of no great size. The dip is here to S. 65° W. at 50°.

Chakimyaung outcrops.

At distance of one to one-and-a-half miles from Minpalaung, in a westerly to north-westerly direction, is a small stream called the Chakimyaungchaung, in which some coal (XII) is exposed.

The coal is inferior in appearance and only 2-ft. in thickness. The dip is to S. W. at 75°:—

Section.

		Ft.	In.
1. Clayey jointed shale	Over	10	0
2. Inferior laminated *coal*		2	0
3. Laminated shale		1	0
4. Jointed brown shale		2	0
5. Coaly shale		0	5
6. Laminated shale (only a few feet seen)		...	...
	TOTAL	15	5

(Coal 2 feet.)

Thaikthaw outcrop.

At Thaikthaw there used to be an exposure of coal which was worked, but the bank has fallen in and concealed it. The shale just here contains nodules of iron pyrites which are used for the manufacture of sulphur.

XIII.—A few yards further up the stream than the old workings a small section containing coal is seen:—

		Ft.	In.
1. *Coal*		1	0
2. Black, jointed shales		4	0
3. *Coal*		1	0
	TOTAL	6	0

(Coal 2 feet.)

Above and below this section is the usual black, jointed shale. The beds are here perpendicular and strike S. 20° E., but 20 yards to the east the finely jointed shales are seen dipping to S. 70°, W. at 60°. At a distance of 100 yards to the north-west of this point, in the jungle, there is an outcrop of 6 inches of coal smut.

Kyatthaungdaung outcrops.

XIV. In a stream on the Kyatthaungdaung there is a small outcrop of coal which is only 2-ft. thick, and very much broken and irregularly laminated. It lies between bands of shale, and the dip is to N. W. at 30°.

Just above this, in the same stream, there is a well exposed section (*XV*), with a dip to W. of 26°:—

		Ft.	In.
1. Shale; top not seen		...	...
2. Pocket of *coal* in shale		2	0
3. Shale with strings and small pockets of coal		11	0
4. Pocket of *coal*, thinning out in a short distance		0	5
5. Shale, black, jointed		3	0
6. Hardened clay band		0	4
7. Much contorted *coal*		2	0
8. Shale, containing a few strings of coaly matter		20	0
9. Much disturbed *coal*		4	0
10. Much contorted band of shale, containing strings of coaly matter		6	0
11. Finely laminated and jointed shale		2	0
12. Band of bright *coal* (thins out rapidly)		1	6
13. Black shale (same as No. 11)		3	0
14. Band of ferruginous hard clay		2	0
	TOTAL	57	3

(Coal 9 feet 11 inches.)

The total thickness of the coal seen here is 9 feet 11 inches, but 3 feet 11 inches of this is in the form of evanescent bands or pockets, while the remaining 6 feet is divided into two portions of 2 feet and 4 feet respectively, separated by 20 feet of shale, besides which the coal is much crushed and contorted.

XVI.—A few yards to the N.W. of No. *XV* is another section containing coal, with a dip to S.W. of 70°—

	Ft.	In.
1. Much contorted black shale (thickness not seen) .	...	...
2. Much contorted *coal*	2	0
Here a small fault runs across the section from N. to S.	...	...
3. Grey, slightly ferruginous shale	4	0
4. *Coal* laminated and contorted	2	0
5. Ferruginous, hard, clayey shale	1	0
6. Black, jointed shale	20	0
7. *Coal* . . . . . Over	2	0
Remainder concealed	...	...
TOTAL .	31	0

(Coal over 4 feet.)

These two sections give another example of the extremely disturbed condition of the beds, for we have them at two spots, less than 50 yards apart, dipping to S.W. at 70° and to W. at 26°, and the beds are seen in the section to be greatly disturbed and contorted.

Two hundred yards to the north of this last section, a small outcrop of coal is badly exposed, and a quarter of a mile to S.W. of this, another section (*XVII*) is seen, though it is badly exposed, in the bank of the stream. The uppermost 30 feet are concealed by the bank having fallen, but there is apparently a small amount of coal there, and some shale can be seen: below this some more coal can be seen. The dip is 60° to S. W.—

Section.

	Ft.	In.
1. Concealed: probably shale	30	0
2. Much contorted and irregularly bedded carbonaceous shale	4	0
3. *Coal*	1	6

The exposure continues with the same dip for about 50 yards down stream, and then a small pocket of coal is seen in the carbonaceous shale.

Kyaulimyaung outcrops.

XVIII.—In the Kyaulimyaungchaung there is a small seam of coal dipping 60° to E. between beds of yellow shale. The coal is very friable and irregularly fractured.

Ludwin outcrop.

The last locality I saw is situated to the north of Minpalaung and is known as the Ludwin. Coal is said to have been formerly worked here in a perpendicular seam, but the hole is now filled up, and all I was able to see was a perpendicular bed of dark shales.

Coal formerly worked.

Coal is said to have been extracted at all these localities in King Mindôn's time, and sent down to the Irrawaddy for use at the Sagaing iron works. The works were all surface quarries, and one or more men worked at each exposure of coal, receiving R8 for each 100 baskets dug out. The coal cost another R16 to transport to the Irrawaddy; on pack-bullocks as far as the Panlaung, and the rest of the distance on bamboo rafts. The price realized, when sold to outsiders on the Irrawaddy, is said to have been R1 per basket.

No prospect of working the coal profitably.

I did not see a single seam which held out any real prospect of being workable. The seams are exceedingly irregular; that is to say, they are not to be depended upon to extend to any distance. A large proportion of the coal consists of mere pockets; and even where this is not immediately evident, and they can be traced for any distance, they are found either to thin out altogether or to decrease considerably in thickness.

Another point which is greatly against the coal is the very large amount of disturbance to which the strata have been subjected. The beds have been tilted up at very high angles and are often perpendicular. There must be a considerable amount of faulting associated with the extreme contortion which the beds have undergone, and the coal has been in many places so much crushed as to make it impossible to extract any but the smallest fragments.

The accompanying table (Table I) shows the variety and high inclination of dips over the area which I visited.[1]

It will be seen that, even omitting the exceptional cases, *XIV* and *XVIII*, the direction of dip varies from S. to W., and the angle from 26° to 90°. It will be readily imagined what a deleterious effect the crushing following on these movements must have had upon the quality of the coal as regards its capacity for being extracted in suitable lumps. Even if the coal were uninjured, the high angles of the dips, and their great irregularity, as pointed out in several cases above, would preclude all possibility of working it at a profit.

As far as I saw, the only place where there is any reasonable chance of the coal being workable, is at the section (No. *VIII)* on the Thabyetaungdan; and if nothing better should be found further north, where there is said to be more coal, it might be worth the while of Government to explore this seam, as advised above.

Area over which the coal occurs.

The coal occurs over an area of 150 to 200 square miles, and within the limits of each group of outcrops the seams are thickly distributed, though they never attain any large size without a large proportion of shale partings, and frequently thin out within a short distance.

Age of the coal.

It appears to be of tertiary age, and there can be little doubt that explorations would reveal more completely the irregular and variable characters so well known in the tertiary coals, and which have been so well exemplified at Thayetmyo. At Thayetmyo the position of the

[1] In order to avoid confusion by introducing the strike of the beds, I have preferred, in cases where the beds are perpendicular, to consider them as dipping 90° in the direction at right angles to the strike nearest approximating to the average direction of dip of the district (= about S. 66° W.).

coal formed an inducement for endeavouring to work it; but here on the Panlaung the difficulties of transport would be so great that, unless an exceptionally good seam were discovered, it would be cheaper to obtain coal for the railway from Rangoon.

Coal assays.

The results of assays of the coal carried out in the Geological Survey laboratory by Mr. T. R. Blyth are very satisfactory, the ash being in most cases very low. A remarkable feature about these coals is the low percentage of volatile matter, which is due to the great disturbance which the coal has undergone. This would influence the burning of the coal to great extent by reducing the amount of flame, and it would therefore be unfitted for furnaces, in which much flame is required.

The table of assays will be found below.

Only one practicable method of working the coal.

I believe that the only means by which it would be possible to work the coal would be that used when it was formerly worked. Then each outcrop was quarried by one or more workmen, and the resulting fuel collected at various points for shipment upon rafts. The irregularity, uncertain thickness, and high dip of the seams would preclude the possibility of working by the ordinary methods of coal-mining.

Means of transit.

As regards means of transit, I was unfortunately unable to obtain the help of Mr. Bagley to go over the ground, as he was unable to leave other work at the time, but I imagine that it would be a very expensive undertaking to make a tram-line up to the coal-field from any point on the Toungoo-Mandalay Railway south of Kyauksè. At least 20 miles would have to be laid even if it could be done in a straight line, which would be impracticable on account of the hills to be crossed; and by no amount of deviation would it be possible to avoid the hilly ground altogether.

Though I have not seen the country to the north, I am inclined to think that the best line would be from the neighbourhood of Kyauksè up the valley of the Panlaung, though this would probably present such engineering difficulties as to make the line very expensive, and the portions of the coal-field which I have explored are not worth it.

Labour at hand.

At present the labour at hand is scarce, and would have to be imported from Hlaingdet or the direction of Nyaungywe. The disposition of such of the people as I saw was decidedly friendly, but they were very timid, and I doubt whether I should have seen any of them if Maung Sein Bôn, who was in charge of the coal workings in King Mindon's time, and whom they knew well, had not been with me.

Coal in Ywangan territory.

The coal is almost all in Ywangan territory, and, as I do not know what the relations of Government are with the ruler of Ywangan, I am unable to give any opinion as to his claims or rights. It would not be worth while for Government to work the coal at present, and I doubt whether any outside parties would care to take the matter up. But after a few years, when the country is settled, the whole coal-field should be examined, and any seams, such as the one on the Thabyetaungdan (No. *VIII*), which give any hopes of successful working, should be further explored.

TABLE I.—*Showing the chief Outcrops referred to.*

No.	LOCALITY.	Direction of dip.	Angle of dip.	Thickness of coal.	REMARKS.
				Ft. In.	
I	Pagamyaungchaung .	S. 45° W.	75°	2 0	A mere pocket of coal.
II	Ditto . .	S. 45° W.	60°	4 0	There is a 9-ft. parting of shale between the two layers of coal, making up this 4 feet.
III	Mithuichetkyauk . .	S. 45° W.	72°	3 3	This thins down in a short distance to 1 foot 6 inches, and there are two other layers of coal near, 1 foot 4 inches, and 6 inches respectively.
IV	Ingôndaung . . .	S. 70° W.	70°	0 8	
V	Ditto . . .	S. 45° W.	40°	1 6	
VI	Ditto . . .	S. 45° W.	90°	6 0	It is doubtful whether this coal is really as thick, and 15 feet off, it is only 1 foot 9 inches.
VII	Ditto { East end .	S.	90° }	3 0	Much crushed and in three layers, separated by 6 feet of shale partings.
	{ West end .	S. 45° W.	80° }		
VIII	Thabyetaungdan . .	W. 20° N.	60°	7 6	In two layers of 2 feet and 5 feet 6 inches, separated by shale and clay. (This is the most hopeful locality I saw.)
IX	Ditto . . .	S.	90°	4 2	With shale partings. The lowest 1 foot is very inferior.
X	Chobinmyaungchaung .	S. 40° W.	90° }	4 6	Opposite ends of the same section.
Xa	Ditto ditto . .	S. 30° W.	90° }		
XI	Chobinmyaungmachaung	S. 65° W.	50°	...	Pockets of shaly coal.
XII	Chakimyaungchaung .	S. 45° W.	75°	2 0	Very inferior.
XIII	Thaikthaw . . .	S. 70° W.	90°	2 0	With a 4-ft. parting of shale
XIV	Kyatthaungdaung . .	W. 45° N.	60°	2 0	Twenty yards to east of XIII, irregularly laminated.
XV	Ditto . . .	W.	26°	9 11	2 feet 5 inches and 1 foot 6 inches consist of pockets of coal, the remainder, 4 feet and 2 feet, is much disturbed.
XVI	Ditto . . .	S. 45° W.	70°	6 0	This is much disturbed, and there is a fault in the section.
XVII	Near Kyatthaungdaung .	S. 45° W.	60°	1 6	There is, in addition to this, a small pocket lower down the stream.
XVIII	Kyaulimyaungchaung .	E.	60°	...	Covered by yellow clay.

TABLE II.—*Results of Assays of some Coals from the Panlaung Coal-field.*

	Pagamyaung-chaung.	Mithalchet-kyauk.	Kyatthaung-daung.	Ingôndaung.	Ingôndaung, Thabyetaung-dan.	Chobinmyaung-chaung.	Chobinmyaung-chaung.	Chobinmyaung-chaung.
	II	III	XIV	VI	VIII	X (1)	X (5)	X (15)
Moisture . .	1·36	15·46	2·82	2·18	2·90	3·04	4·50	2·28
Volatile matter, exclusive of moisture.	14·32	26·48	11·12	18·82	9·18	14·92	30·78	7·26
Fixed carbon .	78·80	50·94	63·16	76·00	73·02	62·18	62·38	60·00
Ash . .	5·52	5·12	22·90	3·00	14·90	19·86	2·34	30·46
TOTAL .	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
	Sinters slightly. Ash, dark reddish brown.	Does not cake. Ash, light yellowish grey.	Does not cake. Ash, light grey.	Does not cake. Ash, light brown.	Does not cake. Ash, light grey.	Sinters slightly. Ash, light grey.	Cakes but not strongly. Ash, light brown.	Does not cake. Ash, very light grey.

3.—TWO COAL LOCALITIES IN THE SHAN HILLS.[1]

Lègaung near Singulèbyin.—I was informed of the occurrence of this coal by the Lônpan Thugyi, who accompanied me from Singu to the place where the coal is to be seen. Lègaung is a small village, about 4 miles from Singu in a southerly direction.

Close to the village of Lègaung, on the road to Kyat Sakan, coal is seen in two places. In the first very little is visible, but it had been exposed by digging, and I was able to make out the following section :—

	Ft.	In.
1. Surface soil	..	...
2. Coal smut	0	4
3. Brown clay	0	9
4. Coal smut	0	2
5. Brown clay	0	6
6. Coal smut	0	1
7. White clay	0	1
8. Powdery coal	0	4
9. White clay ; not gone through . . .	...	...
TOTAL .	2	3

[1] See map 2.

A few yards further on, 3 feet of very powdery coal is seen topped by surface clay and dipping to W. at 40°. It does not look at all promising, nor does there seem to be any chance of its improving to the deep. From the rocks occurring in the neighbourhood it would seem that this coal is like that of the Panlaung of tertiary age.

At about one mile from Lègaung is the deserted village of Titpalwiywa, close to which, in a small, dry water-course, is a coal locality known as Titpalwigôn. Here there are 1½ feet of fair coal between beds of dark grey shale; about 3 feet below the 1½ feet of coal is another foot, but it is not well seen. No other coal is seen in the immediate neighbourhood, and there is no prospect of this being workable. This is also tertiary coal.

Ngu, near Pwehla.—This coal was brought to my notice by Maung Sein Bôn on my return from Fort Stedman, and is situated about 7 to 9 miles north-west of Pwehla on a hill lying about a quarter of a mile from the village of Ngu.

The coal is found in three places on the hill. In the first it is 11 feet thick and dips to the west at 70°; it rests on clayey shale, and contains a great deal of clayey matter and is very soft. It also contains a large quantity of iron pyrites, which is picked out for use in the manufacture of sulphur. In the second exposure, which appears to be a part of the same seam, the coal is perpendicular and, at the level of the water in the stream in which it is exposed, is 7 feet thick, but 20 feet above, it is only 4 feet thick. This is also very clayey, though it contains no pyrites, and it occurs between bands of hard silicified sandstone. The third spot, which I did not visit, is higher up the hill, and the coal there is said to be inferior to that in the other two localities, though it is more valued on account of its containing a larger proportion of pyrites. This is also of tertiary age, though it can hardly be called coal, being rather a carbonaceous shale, as may be seen by an inspection of the results of assays by Mr. T. R. Blyth, a table of which is appended—

	NGU COAL-FIELD.		LEGAUNG COAL-FIELD.	
	From perpendicular outcrop, Ngu.	Ngu, 11-ft. seam.	Titpalwigôn, near Lègaung.	Lègaung.
Moisture	3·08	2·74	2·02	2·14
Other volatile matter	4·00	6·48	12·94	12·06
Fixed carbon	4·62	17·14	72·54	68·32
Ash	88·30	73·64	12·50	17·48
TOTAL	100·00	100·00	100·00	100·00
	Does not cake. Ash, very light grey.	Does not cake. Ash, very light brownish grey.	Does not cake. Ash, reddish grey.	Does not cake. Ash, reddish grey.

From these assays it is evident that this substance is useless as a fuel.

As regards the Lègaung coal, it would make a fair fuel, though the volatile matter is very low, as in all these coals.

4.—On Lignite occurring at Thigyit, near Nyaungwe.[1]

Having been informed that coal was reported by Mr. Scott to exist at Thigyit, near Fort Stedman, and the coal of the Panlaung field not proving so good as was expected, I determined to take the opportunity of being in the neighbourhood to visit the locality.

After much delay I left Fort Stedman accompanied by the Myoôk of Thigyit. Thigyit is situated about 11 to 12 miles due west of Indeinmyo, at the south end of the Nyaungywe lake. The road from Indein is fairly good, but passes over two ranges of hills, and it would hardly be practicable during the rains. The rocks are of the usual character, exposed in this part of the country, namely, massive limestones with red and pink shaly clays and conglomerates.

The so-called coal is situated 2½ to 3 miles to the south of Thigyit, on the road to Mobyè and Rangoon. At this point a small stream, known as the Mithui Chaung, runs across the road, and close by there is a phoongyi kyaung called the Mithui kyaung.

The black substance here exposed, which had given rise to the report of coal, is not true coal, but lignite or brown coal, and though superficially there appears to be a large seam, this, as is seen when it is dug into, is not the case. The lignite can be traced at intervals for a distance of quarter of a mile up the stream from the bridge where the road crosses. The dip of the masses of lignite varies from 15° to 45° to N. W. There are about twenty exposures, some of which are 2 to 3 feet in thickness, and in one case 6 feet. The lignite alternates with grey, yellow, and brown clay.

By digging at a point above the bridge, where one of the 3-ft. layers is exposed dipping to N. W. at 15°, I was able to see the very delusive and irregular character of the deposit, for what looked like a good seam at the surface was found to consist, a few feet below, of—

	Ft.
Clay and surface soil	...
Lignite	2
Brown clay	2
Lignite	2
Brown clay	4
Very brown clay not gone through.	

The lignite is of a plastic nature, containing fragments of fossilized wood, which is also found in the brown clay. The clay contains numerous fossil shells, the larger ones very much crushed: they are evidently of recent origin, and some of the smaller ones, when extracted from the clay, will probably be recognizable, though, owing to their brittle nature, this could not be done in the field.

The whole appearance of this deposit shows that it is the bottom of an old lake, which has silted up in recent times in the same way as the Nyaungywe lake is doing at the present time; and this deposit of lignite is the remains of the plants

[1] See map 2.

which grew there at the time, and of the logs of wood carried into the lake. The conditions are very favourable for the filling up of lakes among these hills, as large quantities of clay are brought down by the streams during the rains: the Nyaungywe lake can be seen to be filling up very fast, and near the banks, especially near the points where streams fall into it and form deltas, it is little more than a bog.

There is no hope of obtaining any large or profitable supply of fuel from this source, though it might well be used for local purposes should any demand arise for small quantities. The supply would always be precarious.

Appended is the result of an assay of some of this lignite by Mr. T. R. Blyth in the Survey laboratory. The high percentage of moisture is characteristic of lignite. From the assay it will be seen that the lignite contains only 66·48 per cent. of combustible matter:

Post-tertiary Lignite from near Thigyit.

Moisture	22·74
Other volatile matter	36·26
Fixed carbon	30·22
Ash	10·78
TOTAL	100·00

Does not cake. Ash brown.

5.—ON THE METALLIFEROUS MINES IN THE NEIGHBOURHOOD OF KYAUKTAT AND PYINYAUNG IN THE SHAN HILLS.[1]

Silver-lead Mines of Kyautat and Bawzain.—Bawzain is a small village in the neighbourhood of Kyauktat, near Pwehla. About 1½ miles to the north-east of the village there is a valley among the hills, the bottom of which is filled with red clay, the rocks of the surrounding hills consisting of limestone. In clefts in the limestone, and below the red clay, a yellow, somewhat calcareous clay, occurs containing the argentiferous galena. The ore is said to occur in blocks and fragments, varying in size from 3 feet across to the size of a pea. I was unable to enter the mines, most of them having been closed for three years, owing to the disturbances in the country; and of the two that had been recently worked, one had been recently abandoned on account of its unsafe condition, while the other, being only worked during the dry weather, had been closed for the rains.

Argentiferous galena near Bawzain.

The larger lumps, which are of too great a size to be readily carried out of the mine, are broken up and brought out with the smaller lumps and the clay in which they occur, and the whole is washed by means of water, which, while removing the clay, leaves the heavier fragments of ore behind. The ore is then collected in baskets and removed to one of the smelting-houses in the neighbourhood. The ore is said always to occur in this manner, imbedded in the yellow clay; and when it occurs in a cleft or fissure of the rock the walls of the cavity are frequently lined with crystalline calcite.

[1] See map 2.

When the ore occurs in a fissure of the rock, a passage is driven along in the clay between the walls of the fissure, which is usually very tortuous and irregular in its course. The mouth of one of these tunnels which I saw was about 3 feet high and 2 feet wide, and running towards north-west at about 45°, though just beyond the entrance it gets narrower and steeper. The whole length of the passage is said to be 300 cubits. Where the ore occurs below the red clay in the bottom of the valley, square shafts, inclined at about 70°, are dug through the red clay, steps being cut till the yellow clay is reached, which is said to be at a depth varying from 50 to 150 cubits. Chambers, as large as the fear of subsidence of the roof will allow, are then excavated in the ore-bearing clay which is removed and carried to the surface. When it is considerd too dangerous to remove any more clay, the place is abandoned and a new shaft put down at a short distance off. Frequently, if not always, one chamber communicates with the air by means of at least two shafts.

Smelting the ore.

Two baskets full of the ore are smelted at a time, the first operation being carried out in a small blast-furnace heated with a charcoal fire.

The blast is produced by means of a pair of bamboo bellows, which deliver the air through a pair of earthenware tuyères at the back of the furnace. There is also an opening below in front, through which the molten lead is manipulated, and which can be closed at the pleasure of the operator. The lumps of ore without previous calcination are put into the furnace with charcoal, and ore and charcoal are added from time to time; and the molten lead drops down into a hollow below, from which it is ladled out into moulds. A large proportion of lead remains in the dark-coloured glassy slag, which is produced, and no steps appear to be taken to recover this; while the only use that is made of the slag is as glass for the manufacture of ornaments. I did not see this furnace at work, but gathered the information through my interpreter from the smelter.

The operation of reducing the two baskets-full occupies a whole day, and the result is ten hemispherical pigs of metal, averaging about 16lb in weight.

These pigs are then removed to a hut close by, where they undergo the operation of cupellation. The furnace used consists of a basin-shaped cavity in which the molten lead lies, over which the fire of logs of charcoal is supported, so that the heating is by radiation from above. The furnace is closed in at the sides, back, and top, and there is no chimney. In front there are two openings, one a large one just above the surface of the molten lead, and a smaller one above, through which the fire is manipulated.

When the lead is all melted, it gradually oxidizes, and the litharge floating on the surface of the molten lead is drawn off by thrusting an iron rod through the lower opening and rotating it in the litharge which clings to it; and by repeating the operation a ball is collected on the end of the rod, which is knocked off and a fresh one collected. This operation is repeated till most of the lead has been oxidised, when charcoal ashes are thrown in to absorb the remainder of the litharge formed, and the fire kept up till a button of silver is formed. The button, which I obtained, and which was said to be the result of the cupellation of ten pigs, weighs nearly five tolas, and the usual result is said to be from four to six tolas.

There are two furnaces, built together side by side, which are used alternately.

Below the furnace is an opening, through which the bed of the furnace can be broken up and removed when it becomes saturated with litharge.

This operation is also said to last about one day; but, as there is very little draught owing to the absence of chimney, the products of combustion being carried off through the upper opening, this must be a considerable waste of time.

The silver is not refined any more, but sold in buttons, the price being, according to my informant, 8 annas per tola of rough silver.

The balls of litharge obtained are taken back to the blast-furnace in which the first operation is performed, and there reduced again by the help of a charcoal fire in the same manner as in the first operation. No provision is in any case made for condensation of the lead fumes, and the loss, both in lead and silver, must be very great. The resulting lead in ten pigs probably weighs about 120lb. I was told 400 viss, but, as only ten are formed, and the one I obtained only weighs 18lb., this is manifestly absurd, and the error probably resulted from the interpreter's very limited knowledge of English. The total profit to the furnace proprietor, who does not work himself but employs a smelter, is said to be about R4 per every two baskets of ore smelted.

Galena at Bwèlôn.

Bwèlôn is a village about 4 miles from Bawzain in the direction of Kyauktat. At a distance of about three-fourths of a mile in a north-east direction from this village is a hill, which is ramified by old workings, some of which are said to run right through from one side of the hill to the other. The argentiferous galena occurs here in the same manner as at Bawzain, in yellow clay in fissures of the limestone rocks. The ore here is, however, richer in silver than that of Bawzain; it is said to give eight tolas of silver to two baskets of ore.

Argentiferous galena at Dwinzu.

Dwinzu is about half-way from Bwèlôn to Kyauktat. It is merely the name of the locality (there being no village in the immediate neighbourhood), which is situated on the banks of the Ngaboi Chaung.

The ore occurs here in the river-bed in the form of pebbles and in a fissure close to the stream. It is said to give 25 to 30 tolas of silver to two baskets of ore, but is not so plentiful as at the other two localities.

Work at the mines stopped.

No work has been carried on either at Bwèlôn or Dwinzu for some years now, but at Bawzain two of the mines had been worked up to a short time before my visit. The Ngwegunhmu, or hereditary ruler, charges a royalty of R1 per month for every man and wife working in the mines and takes one-third of the ore. Kyauktat was visited by the Salween Expedition in 1864-65, and a description of the manner of smelting the ore is given by Mr. F. Fedden in his report on the expedition.[1] He was, however, unable to visit the mines. This source of lead and silver is also mentioned in Captain G. A. Strover's memorandum.[2] I was able to procure enough of the Bawzain ore to furnish an assay, and the result shows 74·29 per cent. lead and 13 ozs. 7 dwt. 20 grs. of silver to the ton of ore by dry assay, and a trace of gold. This would hardly pay to work systematically at the present low price of silver.

[1] Sel., Records, Govt. of India, Vol. XLIX, p. 39.

[2] Reprinted from the *Gazette of India* in the *Indian Econ mist*, Vol. V.

Galena at Pindaya.

Argentiferous galena is also said to occur in the hills near Pindaya, but is not worked on account of the small quantity of silver contained.

Pyrites in the Thaingyi-chaung.

Pyrites near Bawzain and Kyauktat.—About 5 to 6 miles along the road from Pwèhla towards Bawzain, the road passes close to a large stream bed (Thaingyi-chaung), in which is an exposure of dark grey shales. These shales contain a considerable quantity of nodular iron pyrites, which is collected and subjected to distillation in earthenware retorts, in order to obtain sulphur. There seems to have been a considerable amount of sulphur manufactured near Bawzain in former years, but at present all work is stopped. The sulphur is chiefly used in the manufacture of gunpowder.

Pyrites in the Thingèchaung.

About 1½ miles nearer Bawzain is the Thingèchaung where pyrites again occurs in dark grey shales, and is said to be of the same quality as that of Thaingyi-chaung, but less sparingly distributed.

Pyrites near Kyauktat.

Pyrites of the same character also exists near Kyauktat, but I was unable to visit the locality.

Copper at Kyauktat.

Miscellaneous Minerals, &c.—At Kyauktat copper, in the form of green carbonate, associated with quartz, occurs, and is said to yield 5 viss of copper to the two baskets of ore. I was unable to visit this locality.

Copper at Taunglèbyin.

Near Pyinyaung, at Taunglèbyin, on the road from Shwenaungbu to the Shan States, copper ore is said to occur. In some blocks of red serpentine which were brought me from this locality there are some specks of green carbonate of copper.

Gold at Taunglèbyin.

Gold is also said to be obtained by washing in a stream near Taunglèbyin. I tried to visit this locality, but was unable to do so, as it was too far to get there and back to Pyinyaung in one day, and I was unable to procure coolies.

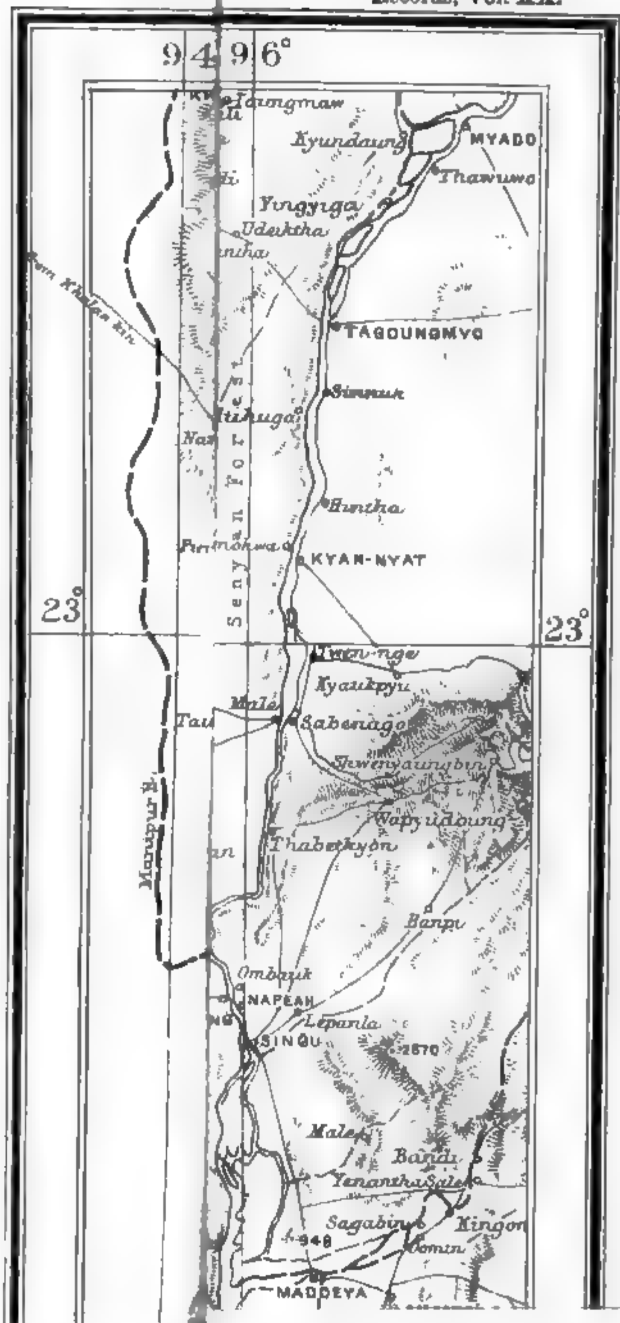
Boring Exploration *in the* Chhattisgarh Coal-fields. (*Second Notice.*) *By* WILLIAM KING, B.A., D.Sc., *Director, Geological Survey of India.*

In my previous notice[1] it was shown that, owing to the poor quality of the coal from the boring assays in the Rampur field, examination should be diverted to the Mand Valley, and, if possible in the time at our disposal, to the Korba country also. These later explorations have been made, with, however, no better success.

Tumidih on the Mand River.—Work was begun, under the most unfavourable circumstances[2] near Tumidih in the Raigarh State, about 20 miles N. W. of Rai-

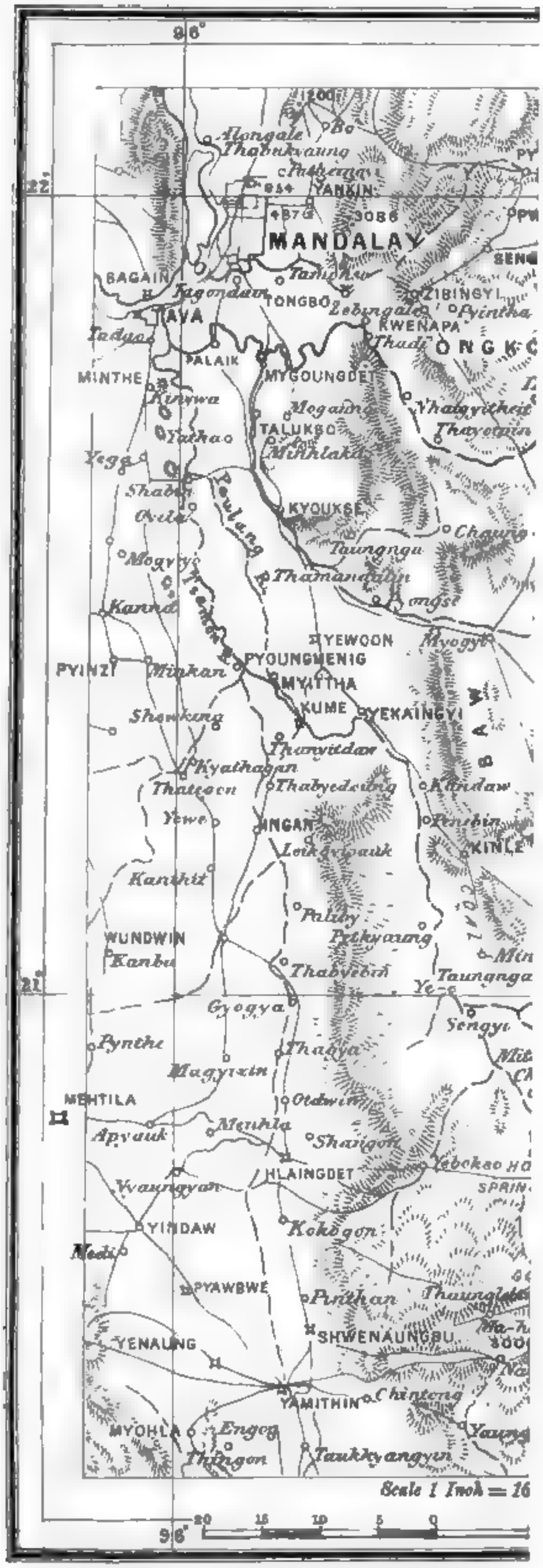
[1] Records, G. S. I., XIX, p. 210.

[2] Following on the death of the Mining Assistant, Mr. Stewart, and the impossibility of replacing him on short notice by a sufficiently competent man, I and my Sub-Assistant, Babu Hira Lal, had in fact to overlook the work.



NOTES ON UPPE

Lithographed at the Survey of



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Lithographed at the Survey of

garh; one of the bore holes (No. 2) entering almost immediately into carbonaceous shales through which it passed at first for some 25 feet, and then again for 20 feet more, but without striking any trace of proper coal. While this was going on, Babu Hira Lal was successful in finding outcrops of coal in the small Pasana or Pasang stream, a short distance to the south, and likewise in the Nagoi tributary, 2 miles to the north of our centre of operations: and thus it was ascertained that we were here on an anticlinal, or flat-arched arrangement of the strata, into the lowest beds of which the two Tumidih bore holes were being sunk, the outcrops exposed in the *nalas* to north and south being in higher beds. Our attention was then directed entirely to the Pasana part of the field: and our hopes were high, for the outcrop showed, at any rate, one band of good-looking coal at least 13 feet thick, out of which, though it was somewhat variable in quality, some 4 or 5 feet of useful fuel might eventually be obtained.

The boring samples as they came up even looked tolerably fair: still there was a suspicious uniformity about them which tallied too closely with those obtained from the other fields, and the old fear of deteriorated samples again became dominant in my mind. These eventually gave such a large percentage of ash that, had it not been for the fair promise of the outcrop, the borings should have been given up at once.

There was nothing for it, then, but to dig well into the outcrop and check the boring samples by comparison with a fair selection of outcrop samples. These were assayed by Hira Lal on the spot;[1] and another series was subsequently tried in the Survey laboratory. There is no use in giving the assays of the bore samples; they were altogether poorer than those from the outcrop, the laboratory assays of which show sufficiently the quality of the coal.

[1] I cannot but record my approval of the willing and workmanlike way of Hira Lal in making these assays at the boring smithy. I have heard complaints of other Sub-Assistants on the Survey objecting to buckle to handiwork which every officer is necessarily obliged to undertake at times; but there was none of this in Hira Lal: on the contrary, he was full of resources, and I have little doubt would have made the clay crucibles had we failed to find them ready at hand in the shape of the little cups used for illuminations.

Outcrop of Coal from Pasana stream, Raigarh State:—Hira Lal seam.

	1st foot.	2nd foot.	3rd foot.	4th foot.	5th foot.	6th foot.	7th foot.	8th foot.	9th foot.	10th foot.	11th foot.	12th foot.	13th foot.	Average of 1st to 13th foot.
Moisture	6·70	4·02	2·54	2·62	4·98	5·20	4·98	3·74	8·36	6·42	5·50	2·58	4·34	4·77
Volatile matter, exclusive of moisture	31·82	24·32	18·36	22·20	24·72	26·24	24·72	20·06	28·56	29·66	27·52	25·02	28·66	25·53
Fixed carbon	44·54	35·40	19·74	27·68	36·58	39·32	30·98	26·18	51·12	44·28	36·96	20·40	31·30	34·20
Ash	16·94	36·26	59·36	47·50	33·72	29·24	39·32	50·02	11·96	19·64	30·02	52·00	35·70	35·50
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
	Ash, light reddish brown. Does not cake.	Ash, gray. Does not cake.												

This coal is quite unfit for railway purposes; the 1st and 9th foot, in a thickness thirteen feet, being alone up to the standard of average Indian coal.

The boring also showed a higher seam than that just described, its outcrop, if y being concealed under the water and sand of stream. Samples of 19 feet of this om the borings were assayed in the laboratory with the following result:—

Samples of Coal from Seam in No. 3 Bore-hole, Pasana River, Mand Valley.

DEPTHS IN BORE-HOLE.	23rd foot.	24th foot.	25th foot.	26th foot.	27th foot.	28th foot.	29th foot.	30th foot.	31st foot.	32nd foot.	33rd foot.	34th foot.	35th foot.	36th foot.	37th foot.	38th foot.	39th foot.	40th foot.	41st foot.	Average.
Moisture .	4·86	4·82	4·62	4·54	4·74	5·12	4·84	4·94	4·56	4·24	4·48	3·80	3·62	3·44	3·36	2·76	3·36	3·00	2·88	4·10
Volatile matter (exclusive of moisture).	24·78	25·74	24·82	25·66	26·36	25·94	25·36	25·94	24·44	29·64	23·24	27·44	24·24	23·48	22·80	21·20	21·92	21·54	20·06	24·46
Fixed carbon	30·30	30·92	28·92	30·24	30·98	33·22	30·46	29·12	26·36	20·46	24·68	28·00	22·82	22·42	23·32	22·12	24·12	22·90	21·68	26·49
Ash . .	40·06	38·52	41·64	39·56	37·92	35·72	39·14	40·00	44·64	45·66	47·60	40·76	49·32	50·66	50·52	53·92	50·60	52·56	55·38	44·95
TOTAL .	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

N.B.—Does not cake. Ash, light grey.

Four bore holes were run down in this area, by which it was ascertained that there are two other seams, four in all, above those assayed; but they are thin and inferior in quality. The area containing these is very small, only about a square mile in extent; quite large enough however, had either of the thick seams been of any good, to have given a large amount of fuel.

The representatives of the same measures to the north of Tumidih, on the Nagoi side, are even poorer than those of the Pasana *nala*, being merely a succession of grey and carbonaceous shales, with thin bands, or layers, of inferior coal; and this condition of affairs only agrees with what had already been observed for many miles to the north by Mr. Ball and myself. There was therefore really no use in wasting more time or money in this direction.

Korba, and its neighbourhood.—Two borings were started at Korba, on the river bank opposite the town; and a cross-cut was made in the great exposure or outcrop of shales and coal in the river bed. Two borings were likewise put down near Sumheda, or rather Ghordewa, on the Aharan river, near Hira Lal's outcrop,[1] into which a fresh cut was made.

Korba.—The cutting in the Hasdu was made in the most favourable-looking part of the outcrop, or about the middle, and gave us samples of 38 feet of the coal and shale. Thirty-five feet of this gave an average of 34·15 of ash. The best assays were:—

Number of feet.	Moisture.	Volatiles, exclusive of moisture.	Fixed carbon.	Ash.	Colour of ash.
1st	6·04	29·44	43·60	20·92	Brownish.
2nd	6·18	29·04	42·26	22·52	
16th	6·20	27·40	47·50	18·90	„
17th	5·64	26·44	40·76	27·16	
18th	4·44	31·90	43·10	20·56	
31st	7·44	26·40	45·32	20·84	„
37th	7·98	27·72	42·46	21·84	„
38th	8·64	27·00	45·64	18·72	„

It is very difficult, if not impossible, to compare the results in this cross-cut with those ascertained in 1870 during Mr. Blanford's examination,[2] for the latter was made by cuttings at good places throughout the whole measured outcrop, and it may be that Hira Lal did not touch on the 4 feet of good coal noted by Mr. Blanford, which gave the average:—

Carbon 57·5. Volatiles and moisture 25·2. Ash 17·3.

The lower two feet yielding—

Carbon 60·5. Volatiles and moisture 29·5. Ash 10·0.

But we can fall back on the boring, which, though not made in the bed of the river and thus in the coal outcrop, was nevertheless run down in the inland western

[1] Records, G. S. I., XIX, p. 223, 2nd para.

[2] Records, G. S. I., III, p. 54.

extensions of what appears to be the same seam through 69 feet of shale and coal, the thickness of the great seam at that point. Unfortunately there is no such good band of coal shown by the boring samples; all the coal is bad; and, again, a list of the samples recorded by us would be only a wearisome tale for tabulation or reading in the present paper. The average ash is 37·28 per cent.; and the only section of the bore hole worth looking at is as follows :—

No. of feet in seam.	Moisture.	Volatiles, exclusive of moisture.	Fixed carbon.	Ash.	Colour of the ash.
59th . .	5·92	28·36	37·40	28·32	
60th . .	5·82	27·28	39·28	27·64	Brown.
61st . .	6·00	27·20	39·14	27·66	
62nd . .	5·12	24·56	42·32	28·00	

This 4-ft. band may answer to Mr. Blanford's band "*h*:" but in any case the whole series of assays from this boring go very much against the outcrop, while they again cast a cloud of doubt on the reliability of boring assays.

I examined all the country on the Korba side of the river and the outcrops in the Sitamanda and Kachendi streams, but without finding any improvement on the coal of the main outcrop.

Ghordewa.—Owing to lateness in the season we were only able to start two borings at this place, the first of which, at 429 feet from the outcrop and on the dip, went through the coal at 72 feet from surface (we had calculated on 70′—80′). The other boring No. 2 was estimated to cut the coal at 200 feet from the surface, but could only be carried down 153 feet. Here, for a wonder, the boring assays have not be-lied the promising outcrop to anything like the damaging extent exhibited in other parts of Chhattisgarh; but so remarkable an exception, for these fields, in the way of outcrop and boring assays must be well corroborated before venturing on colliery development.

The seam at the outcrop is 5 feet 3 inches thick; and the fresh cut made in it yielded assays as below :—

Analysis of Coal from the Outcrop in the Aharan between Sumedha and Ghordewa.

No. of feet.	Moisture.	Volatile matter, exclusive of moisture.	Fixed carbon.	Ash.	Colour of the ash.
1	8·80	25·80	57·42	7·98	Greyish.
2	5·56	17·58	48·96	27·90	”
3	7·78	28·84	55·74	8·02	”
4	8·40	28·28	56·36	6·96	”
5	8·32	30·58	52·42	8·68	”
Average excluding No. 2 .	8·32	28·37	55·48	7·91	...
Average of the whole seam .	7·77	22·21	54·18	11·90	...

On the other hand, the boring shows the coal to be somewhat thicker, six feet having been pierced; though this must be reduced a little on account of the dip The samples from it give the following results:—

Analysis of Coal from boring north of Ghordewa.

Number of feet from the surface.	Moisture.	Volatile matter, exclusive of moisture.	Fixed carbon.	Ash.	Colour of the ash.
72nd . .	5·28	28·20	52·30	14·22	Brown
73rd . .	5·52	29·76	52·14	12·58	
74th . .	5·22	27·06	52·92	14·80	
75th . .	5·16	27·58	53·96	13·30	
76th . .	5·34	27·80	54·70	12·16	
77th . .	5·20	21·08	39·34	34·38	
Average, excluding No. 77 . .	5·30	28·08	53·20	13·41	...

The lowest foot of the boring samples can only be called a shale, a condition to be reasonably expected in a coal seam, thus leaving nearly five feet of fairly good coal, as Indian coals go. A comparison with the outcrop assays will show, however, that even in so short a distance as 429 feet, the layers of the seam do not keep up uniformity, there being no bottom layer in the outcrop answering to the shale of the bore section; while the latter has no representative of the stony band (second foot from top) of the outcrop. All, then, that can be safely reckoned on is about 4 feet of coal throughout; say, in a circle whose diameter is 429 feet: it being quite possible, of course, that such a condition of affairs may exist far beyond so limited an area as this. Extended boring can only prove an extended area.

Résumé of experience gained.—I have now examined by boring, and I think sufficiently so, the separate areas in Hingir, Rampur, and the Baisandar valley, which have been grouped as—

A. Lillari valley,
B. Oira valley,
C. Baisandar valley,

under the one official heading of the Rampur coal-field.

The best seams of the Lillari valley borings gave average ash percentages at[1]:—

No. 1. Chowdibahal	44·18
No. 5. Kaliabahal	44·43
" "	40·23
No. 6. Bonjari	39·31

The Oira valley borings yielded coal carrying 42·71 per cent. of ash, or worse. The Baisandar valley gave no better assays: but here, for the first time, some doubt arose as to the possible unreliability of boring samples, owing to the difference observed between outcrop and bore samples.

No better results have been obtained from the latest borings in the Mand valley or from Korba itself.

[1] Records, G. S. I., XIX, 210.

On the boring assays alone, these coal-fields must be generally condemned as being unlikely to yield good workable and useful coal within the areas tried; and when I write "areas tried" I am practically condemning a very large extent of country indeed, in which, however, there is plenty of room for chance local developments that might pay private enterprise. Now, this, though a deliberate and sweeping condemnation, based on what has always hitherto been considered conclusive evidence, namely, the poorness of boring assays, does, on the face of it, seem too strong for so very great an area of coal-measures, carrying generally two very thick seams of shales and coal besides many other thin ones. Indeed, particularly so, when even the shadow of a doubt has been cast upon the reliability of the boring samples, and while such a promising local improvement shows itself at Ghordewa.

The chances that the boring samples have in some, if not many, cases been spoiled by admixture with foreign and deleterious débris of shales, and perhaps a little sand, are considerably reduced by our close and severe examinations of the Pasana outcrop and borings in the Mand valley; but they are not altogether eliminated, and, when the interests involved in the existence of coal in this part of the country are so great, it would, I think, be folly to leave the exploration in so unsatisfactory a state.

There is little use, however, in having more borings put down unless some more perfect apparatus and more skilled and reliable boring experts can be employed than have hitherto been available. The more immediately feasible plan is to have a small pit sunk on or near the site of some of the old borings in order that the seams they touched or ierce d should be tried in bulk.

The difficulty is to settle on a site, for I cannot point to one place as being preferable to another for its outcrops and bore samples. Such being the case, I fall back on a position as conveniently situated for railway purposes as possible. The Rampur coal-field has this advantage, and it is next nearest for possible supply to the Bengal fields, on the eastern side of the Peninsula. The boring assays from here give as much promise, bad as it is, as from anywhere else; the seams are of fair thickness, the depths at which they were encountered not being excessive; while the shortest distance from the proposed line of railway is only about 4 miles. By the journals or sections of No. 1[1] bore hole near Chowdibahal, a 7-ft. seam occurs at 77 feet from the surface, and there is another seam, 8 feet in thickness at 142 feet. This bore hole is at a good distance from the outcrop, so that there is no fear of any deterioration of the coal, such as, it may be, from proximity to weathering influences; and, as the depth is not excessive, a small pit might be run down on it. As the seams are reached, they should be well cut into, when the con ditions of their coal ought to settle the fate of the Rampur coal-field beyond dispute.

The next best situated place, though it be about 20 miles in a direct N.—S. line from the railway trace, is Korba: and it has these points about it, namely, that there is a great seam manifest to the eye of doubting and practical men of what looks like what ought to be coal, though it may have any amount of shale associated with it; and above all that so excellent an authority as Mr. W. T. Blanford did in the first instance report very favourably on it, and pointed out bands the better portions of which, from the evidence before him, he considered "equal in quality to

[1] Records, G. S. I., XIX, p. 226, and plate, fig. 1.

any coal found in the Ranigunj field." Of course, this opinion of Mr. Blanford was somewhat qualified by the assays received by him at a later date. A small trial pit could be easily run down here on the site of our boring to a total depth of 94 feet, which would pass through the entire seam and show in fair bulk the constitution of the many coal bands.

Local improvement.—That places of better promise may eventually be found is shown by the case near Ghordewa on the Aharan river, which is only about 5 miles west-north-west of Korba; but, as stated in the previous paper, to go on searching for such would be very much like looking for a needle in a bundle of hay. The Ghordewa case remains, however, and it certainly is promising enough to demand further exploration as to the extent and quality of its coal. The place is about 40 miles north-west of Bilaspur, and its shortest distance due south to the Bilaspur-Champa section of the Nagpore-Bengal Railway trace is about 25 miles: it is thus further from railway development than any other spot I have thought[1] worthy of examination, the Baisandar valley excepted. The great feature about it is that the outcrop gives the best 4 feet of coal known to exist in Chhattisgarh, and that the bore assays prove that it does not deteriorate to the deep. Hitherto, we have found such assays giving a decided and damnatory deterioration at only a few yards from the outcrop, but the assays in this case were made on material procured at 143 yards distance. The fear in my mind arising from what I have seen in many areas of these coal measures, in the case of a clean seam of coal—that is without much shale,—between thick beds of fine and uniform sandstones, is that the seam may not be very extensive: but this is no fair ground for deterring exploration. I think, on the whole, there is really more chance of finding by boring that the coal of the Ghordewa area shall continue as good and as thick over an area, say, of a couple of square miles, than that a pit shall show in any of the other localities that the coal is so much superior to the stuff brought up from the borings as to be extensively useful for railway consumption.

Note.—The Chhattisgarh coal-fields have, previous to this paper, been referred to in the following published accounts:—

W. T. BLANFORD.—*Report on the Coal at* Korba *in the* Bilaspur District. Records, G. S. I., III, p. 54.

" " *Note on the Occurrence of* Coal, east of Chhattisgarh *in the country between* Bilaspur *and* Ranchi. Records, G. S. I., III, p. 71.

V. BALL.—*The* Raigur *and* Hingir (Gangpur) Coal-field. Records, G. S. I., IV, p. 101.

" " *The* Raigarh *and* Hingir Coal-field. Records, G. S. I., VIII, p. 162.

" " *On the* Coal-bearing rocks *of the valleys of the upper* Rer *and the* Mand *Rivers in* Western Chutia Nagpur. Records, G. S. I., XV, p. 108.

W. KING.—*On the selection of* Sites *for* Borings *in the* Raigarh-Hingir Coal-field. Records, G. S. I., XVII, p. 123.

" " *Sketch of the Progress of Geological Work in the* Chhattisgarh Division *of the* Central Provinces. Records, G. S. I., XVIII, p. 169.

" " Boring Exploration *in the* Chhattisgarh Coal-fields. Records, G. S. I., XIX, p. 210.

[1] It may be mentioned that there is a very promising field in this same great area of coal-bearing rocks in the Uprora-Lakhanpur country, but this is too out of the way and difficult of approach for consideration in the present railway system. It is on the eastern extension of the Southern Rewa coal-fields.

Some remarks on Pressure Metamorphism *with reference to the Foliation of the* Himalayan Gneissose-Granite; *by* COLONEL C. A. McMAHON, F.G.S.

A few years ago the theory found favour with some geologists that granite was the product of the extreme metamorphism of slate, sandstone, and other rocks of sedimentary origin, and that this metamorphism was the result of the heat developed by the compression of strata in the course of mountain formation. As there were serious chemical and other difficulties, however, in the way of the acceptance of this hypothesis, it gradually lost its hold on the geological mind, and another one, the converse of that above alluded to, now holds the field and seems likely to acquire especial prominence in the future in connection with the geology of the Scotch highlands.

The application of the first theory to the Dalhousie rocks I considered in my paper on the geology of that region (Records, XV, 39, 45, 46), and I came to the conclusion that the granitic structure of the gneissose-granite was not due to heat produced by pressure. The principal argument on which I relied was, shortly stated, as follows; if the heat which produced the granite structure were the product of local pressure, one would expect to find the greatest thickness of granite, and the most perfect granitic structure, developed at the point of greatest pressure; whereas, in the Dalhousie region, the contrary is the case, and at the point of greatest strain the gneissose-granite exhibits its minimum thickness and maximum amount of foliation.

In my previous papers, however, I did not consider whether the ascertained facts could be explained by the pressure metamorphism theory, and I now propose to offer a few remarks on this subject.

The pressure metamorphism hypothesis, shortly stated, may be said to consist of two parts. It is known as a fact that solid bodies such as lead, limestone, ice, &c., can, under the influence of great pressure, be made to flow; and from this fact the advocates of the pressure metamorphism hypothesis infer that many square miles of solid crystalline rocks have flowed with the plasticity of treacle under the influence of enormous pressure. This theory further supposes that when rocks are set in motion in this way the shear, and friction, develope sufficient heat to fuse, or dissolve, the minerals of which the rock is composed and that recombinations of the chemical constituents, and recrystallization, take place on cooling. This hypothesis, it will be observed, is a very comprehensive one and likely to be very useful to the puzzled geologist in the field. The conversion of a granite into a mica-schist can be accounted for by the application of the first part of the theory; whilst the conversion of a mica-schist into good granite can be explained by the second branch of the hypothesis.

I have no present wish to enter the lists against this theory, as a theory; indeed I have myself called in the aid of pressure to account for the foliation observed in the Sutlej diorites and lavas and the production of hornblende schists in that locality (Records, XIX, 80—83); all that I propose to do is to consider whether the facts ascertained regarding the gneissose-granite of the N. W. Himalayas, and recorded

in my previous papers, harmonize with the theory that the foliation of that rock was produced by pressure applied *after* its consolidation *as a granite.*

As I have discussed this question in an article on the gneissose-granite of the Himalayas recently published in the Geological Magazine (p. 212, May 1887), I think it will suffice to give an extract from this publication. It may be convenient to the future student of the Himalayan gneissose-granite to have his attention directed to this branch of the enquiry in connection with these papers—

"The cause, or causes, which result in the foliation of igneous rocks is a subject which at present occupies the attention of many geologists, and seems likely, in the near future, to lead to some discussion. In view of this, a short account of the foliated granite of the Himalayas may be of interest. It may be as well, however, to preface my remarks by saying that I believe that foliation may be produced in several distinct ways, and the explanation which I offer of the mode in which the foliation of the Himalayan granite has been brought about is only intended to apply to the case of that granite.

* * * * * *

"*Cause of the Foliation of the Gneissose Granite.*

"A realization of the eruptive character of the rock described in the above pages removes many difficulties from the way of the Himalayan geologist. "Despite the wonders performed by flexure of strata in mountain regions," wrote Mr. Medlicott, the Director of the Geological Survey of India, in his Annual Report for 1883, "the structural features presented by this rock in certain cases were impossible of satisfactory explanation on the supposition of its being a really stratified gneiss." But if the eruptive origin of the gneissose-granite be admitted, the further question arises whether the foliation observed in it was produced prior, or posterior, to the consolidation of the rock. In considering this question, I leave out of sight altogether evidence of fluxion structure as being really irrelevant to the question at issue, though I think it material to state that the rock does show very decided evidence of fluxion. Without laying any stress on this fact, however, I think the following considerations prove that the foliation was not produced by pressure acting on the rock after its consolidation.

"First, the granite is not always foliated at its contact with the rocks into which it has been intruded; on the contrary, though still porphyritic, it is not unfrequently decidedly granitic along its margin. This fact presents no difficulty to the acceptance of the hypothesis advocated below, but I think it offers an insuperable barrier to the acceptance of the view that the foliation was produced by pressure. Simple pressure will not do: that would not explain the crumpled micas and the very decided evidence of flow or fluxion. Pressure resulting in shear motion, the development of heat and concomitant chemical and mineralogical action, might possibly account for the fluxion structure; but if shear and motion were established on the grand scale required after the consolidation of the rock, the granitic portions along the margins could not possibly have escaped the effects of this action.

"Secondly, the apparently capricious passage from a granitic to a foliated structure in the main mass of the granite is another serious impediment in the way of the acceptance of the theory of dry pressure.[1]

"Thirdly, the conjunction of the outer band of gneissose granite at Dalhousie with the carboniferous series presents another almost insuperable difficulty. The outer band is the most intensely foliated of all the Dalhousie granite. Parts of it look as if it had been rolled under a gigantic steam roller. Unquestionably it has been subjected to very great pressure, and to either traction or shearing; and yet this rock is chock and block with little altered black carboniferous rocks. He who would apply the dry-pressure theory to explain the intense foliation of the outer band of granite, would have to invent a new set of conditions out of his inner consciousness and bring some other rock into position next the granite before he applied the squeeze.

[1] I use this expression as a short term to indicate pressure appled *after* the consolidation of a rock, though of course, I am aware that pressure so applied may produce heat and even fusion

"Fourthly, the condition of the long tent-peg-like splinter of schist included in the granite, alluded to above,[1] shows conclusively that the granite at the point where the inclusion was found was not subjected to extreme pressure of the character under consideration after its consolidation. Had it been, the splinter of schist would have been flattened to a wafer. A mere glance at the plate, a photograph reproduced by the heliogravure process, will show this at once.

"Fifthly, neither the crypto-crystalline mica, nor the fish-roe quartz, described *ante*, can possibly have been produced by the grinding down of the mica and the quartz in the consolidated rock, or by any analogous process; for, besides the crypto-crystalline mica, and the fish-roe quartz, we have very numerous *large* crystals of muscovite, biotite, and quartz. The muscovite and biotite are large and beautiful specimens of these minerals, and they orient in all directions and at every angle up to a right angle to the strings of crypto-crystalline mica. Mechanical action potent enough to have reduced mica to the pulpy condition of the crypto-crystalline mica would not have left the larger micas untouched. Similarly, the fish-roe quartz not only fills cracks in felspars, and forms a sort of setting to quartz grains, but it meanders about in the interior of large quartz grains, and terminates abruptly inside them, in a way that does not suggest to the observer that he is looking at cracks stopped with micro-crystalline quartz, but rather that the crystallization of the quartz was brought to a comparatively rapid termination towards its close.

"Indeed, properly considered, I think the crypto-crystalline mica, and the fish-roe quartz, furnish a clue to the riddle. I may mention in passing that I have observed in a felsite patches of material closely resembling the crypto-crystalline mica mixed up with the quartz and the ordinary felsitic base; but I desire more particularly to refer to a series of rocks which occur in the peninsula of India about eighty-five miles nearly due west of Delhi. We have there a very interesting group ranging from felsites, quartz-porphyries, and granite-porphyries to almost true granites. The felsites appear to be true lavas; and the others, though merging gradually into rocks of plutonic character, are probably more or less directly connected with them. These rocks never show any trace of foliation, or give any indication of crushing. But what is important to note is, that the gradual genesis, so to speak, of the fish-roe quartz may be observed in these rocks. The quartz gradually becomes more and more developed in the felsitic base; it begins to crystallize out in grains of microscopic size, and the grains increase in number, until at last the whole base, or ground-mass, of the granite-porphyries partakes closely of the characters of the fish-roe quartz of the Dalhousie granite. The true explanation of the foliation of the latter rock I believe to be briefly as follows:—The rock had partially consolidated before it was moved into place; large porphyritic crystals of felspar, and numerous micas and quartz grains had formed; it was very much in the condition of a felspar-porphyry, or a granite-porphyry; when, in the course of the earth-movements that were contorting, crumpling, and folding the strata of the Himalayas, this imperfectly consolidated granite-porphyry was forced through the faults that had been formed along the axes of over thrust-folds; the semi-plastic mass was subjected to enormous pressure; the mica was crumpled; the crystals of felspar were cracked and ruptured; and so much of the micaceous siliceous materials as remained unconsolidated were forced into the rents made in the already formed minerals. The final consolidation took place under conditions of continued strain; but before it was actually accomplished minor and subsidiary eruptions took place which forced new supplies of the granitic material into fissures formed in the previously injected rock, and this fresh material consolidated under conditions somewhat different from those of the first eruptions.

"I think this view meets all the difficulties of the case, and that the intelligent reader will with its aid be able to harmonize all the facts stated above without detailed exposition on my part."

[1] See Records G. S. XVII, p. 168.

A list *and* index *of papers on* Himalayan Geology *and* Microscopic Petrology, *by* COLONEL C. A. MCMAHON, F.G.S., *published in the preceding volumes of the Records of the Geological Survey of India.*

LIST OF PAPERS.

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ADDITIONS TO THE MUSEUM.

FROM 1ST JULY TO 30TH SEPTEMBER 1887.

Five specimens of jade, from the jade quarries, Burma.
PRESENTED BY DR. R. ROMANIS, BURMA.

Nineteen pieces of garnet from Jaipur, cut and polished, valued at Rs. 19-1-2.
PRESENTED BY THE JAIPUR DURBAR, JAIPUR.

A piece of amber containing insects, from Palmnicken, near Königsberg, East Prussia.
PRESENTED BY DR. F. NOETLING.

ADDITIONS TO THE LIBRARY.

FROM 1ST JULY TO 30TH SEPTEMBER 1887.

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The 20th September 1887.

Government of India Central Printing Office.—No. 12 D. G. Survey.—20-12-87.—720.

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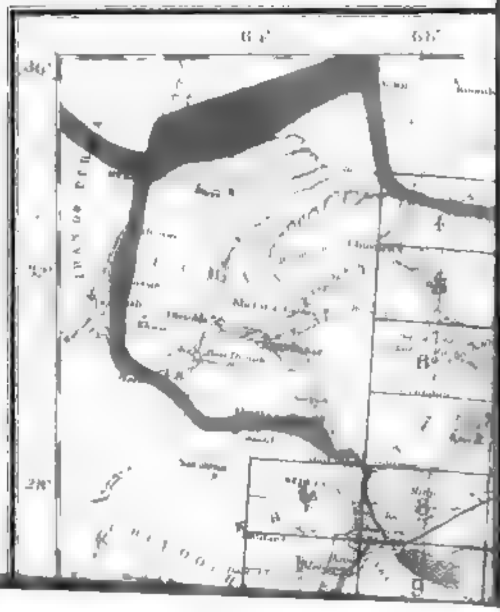

RECORDS

OF

HE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXI.

ublished by order of His Excellency the Governor General of India
in Council.

CALCUTTA:
SOLD AT THE OFFICE OF THE GEOLOGICAL SURVEY,
(AND BY ALL BOOKSELLERS).
LONDON: TRÜBNER & CO.

MDCCCLXXXVIII.

CALCUTTA:
PRINTED BY THE SUPERINTENDENT OF GOVERNMENT PRINTING, INDIA,
1888.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1888. [February.

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1887.

Personnel of Survey and General Distribution.—On taking over the Directorship of the Survey in April last from Mr. Medlicott, I found the Staff of the Survey still below the normal number, owing to vacancies a long time unfilled; or under its effective strength through some of the officers being detached on special work.

The distribution over so vast an area as the Indian Empire, was as follows:—

Mr. Foote, on special deputation to the Mysore Government.
,, Mallet, Museum and Laboratory.
,, Hughes, special deputation with the Deccan Company, Hyderabad.
,, Fedden, Vizagapatam.
,, Hacket, Rajputana.
,, Griesbach, just returned from Afghan Boundary Commission.
,, Oldham, Salt Range.
,, Bose, Chhattisgarh.
,, La Touche, Assam.
,, Middlemiss, Himalayas.
,, Jones, Upper Burma.

Except from Mr. Hughes, who does not furnish us with any reports, satisfactory, and in some cases important, work has been carried out by all the officers named, though it has been of too detached a character to make any particular show in the progress map appended to this report.

Two of the vacancies have since been filled up in the appointment of Dr. Fritz Nöetling (Berlin University) as Palæontologist, and of Mr. Philip Lake (Cantab.) as Assistant Superintendent.

Mr. Mallet is again absent on sick certificate from 26th June for one year; Mr. Jones officiating for him as Curator and in charge of the Laboratory, though he is ready at the same time for any special and short field exploration. Mr. Hughes' deputation with the Deccan Company will not cease until 15th May 1888: and the

placing of Mr. C. L. Griesbach's services at the disposal of the Foreign Office for employment as Geologist to His Highness the Amir of Afghanistan for two years has just been sanctioned.

Perhaps for the first time, so large an indent has been made on us by Native States for deputation on special enquiries, a diversion from the proper work of the Survey which can hardly be avoided, although the officers can be ill-spared where so much having an economic value has yet to be worked out in the geological formations, the limits or relations of which are being systematically followed out. It is a distinction also, that the services of Mr. Foote and Mr. Hughes should have been specially asked for by the Mysore Durbar, and the Deccan Company respectively; while it is eminently satisfactory that their services have been, and are, appreciated. Mr. Foote has completed his deputation; but a still further call has been made on us by the Kashmir Government, and for this duty Mr. La Touche was selected.

The sudden death of Mr. Francis Fedden at Vizagapatam, on the 27th December last, has deprived us of one of our oldest colleagues, who had only just attained the long-waited-for promotion to the 1st grade.

The progress and occupation of the Survey has been in the following order:—

SOUTH INDIA.
Mr. Foote.
Mr. Fedden.
Mr. Lake.

Peninsular Region.—Mr. Foote has the Madras Presidency with its immense area of the crystalline rocks, or gneisses, among which, however, he is still carrying out his latest distinction of a newer (Dharwar) series. At present the great interest attaching to this series of transition rocks is not so much that it may fall in with, or represent, some or all of the various transitional formations of Central India, which have been treated of by so many of us under the names of Bijawars, Aravalis, Champanirs, and Chilpis: but that it is the series in which auriferous reefs are more particularly developed in the Madras Presidency.

Mysore and Bellary country: Dharwar series; auriferous.

I, myself, having had to work out the auriferous rocks of the Wainád region, which certainly appeared to me to occur among bands of the older gneisses, am unable to follow Mr. Foote throughout the whole of his generalizations, which would seem to tend towards an extension of the Dharwars into Wainád; but the fact still remains that he is perfectly clear as to the Mysore country to which his attention has been more thoroughly devoted. In this way he has become the best gold man we have; not an expert in the common acceptation of the term, which is properly a man capable of exploiting a region where gold is known to exist in greater or less quantity, but a geologist, experienced, *par excellence*, in the kind of rocks, or the particular formation likely to be auriferous in India.

The result of his deputation to the Mysore Government has been a lengthy report, founded on an extremely rapid tour over the very large area exhibiting gold indications in that State. I cannot but express regret that the time at Mr. Foote's disposal for examining such a large tract of country was all too small for the questions or the interests involved. His examination, such as it was, stands however, as the most reliable and scientific record of the auriferous veins of the country. To a very large class of men interested honestly in the occurrence of gold in Mysore, Mr. Foote's report is no doubt disappointing, because it fails to paint in glowing colours tracts of quartz reefs, or areas of gold washings which they believed, or had been persuaded to

believe were promising; or that it shows that the evidences he considers hopeful in other tracts were not thought worth other than passing examination by previous explorers. This is only in the nature of such an investigation, more especially since the deputation was to report on the auriferous tracts already visited by Messrs. Lavelle and Marsh in the previous year. Mr. Lavelle was the pioneer of the Kolar workings, and, what is far more to the point, a most successful pioneer. Mr. Foote's report was not suitable to these Records, but its material will be embodied in a paper shortly to be published.

Mr. Philip Lake, the junior Assistant Superintendent, has been placed under Mr. Foote's charge for the present; and it is pleasant to hear that there is much promise of the Survey having again gained by the judicious scheme of selection in the recruiting of our staff, introduced and most strictly watched by my predecessor Mr. Medlicott.

VIZAGAPATAM.

Mr. Fedden, who was transferred to the Madras Presidency at the end of 1886, took up work in the Vizagapatam District, an endeavour thus being made to fill in the large unsurveyed gap between the Godavery and the Ganjam Districts in the Northern Circars, and he had been going on steadily with his survey, but so far without finding anything of particular interest. His untimely death has practically stopped any chance of this district being further examined during the present season.

CENTRAL PROVINCES.
Self.
Mr. Bose.
Sub-Asst. Kishen Singh.
" *Hira Lall.*

My executive work closed with my boring experiences in the Chhattisgarh Coal-fields, the results of which are given in the concluding part of the last volume of the Records. These results show practically that throughout the whole area, as far as it is convenient to the trace of the Nagpur-Bengal Railway, there is only one tract near Korba which has shewn itself, by the borings, at all worthy of consideration as a likely place for workable coal of good quality. The credit of this find, which though it be among coal measures already known, is due to Sub-Assistant Hira Lal, who so far, and in this way, has done credit to the grand training he had under Mr. Hughes. A single boring, at the end of the season, when of course work could not be finished, has proved that this coal of Gordhewa does not change for the worse to the deep, as has unfortunately been the case with nearly all the other borings in other parts of the area.

CHHATTISGARH COAL-FIELDS.

I could not but marvel at this disparity between boring and outcrop samples, which certainly seemed to show that the boring samples might not be so free from admixture with shales as one is generally led to expect in work of this kind. Undei these circumstances, and considering the interests involved, I have felt bound to recommend small trial pits as the readiest method—in the difficulty of getting improved boring plant or trustworthy workmen—for ascertaining the quality of the coal in bulk. Such pits are to be tried near Hingir, and at Korba; and further borings should be put down on Hira Lal's seam at Gordhewa to ascertain the area of that field.

TRANSITIONS AND VINDHYANS.
Mr. Bose.

In the early part of the season I devoted some time to the western edge of the great Chhattisgarh basin, where Mr. Bose had worked in previous seasons among the Vindhyans and Chilpis, though he had then failed to satisfy Mr. Medlicott or myself as to his

capabilities for distinguishing these two series in detail, or for the reporting on or mapping of them. However much he may have failed to satisfy us in this way, it is necessary to state that he did, after all, recognize an unconformity between the two; and under very exceptional conditions of stratigraphy. Mr. Bose was to have continued the work in this region; but even from here it has been necessary to move him, to more urgent, and as it turns out very interesting work, at the manganese ores near Gosalpur in the Jubbulpore district.

The Manganese ores of the Jubbulpore District.

I have just returned from an inspection of Mr. Bose's work as far as it has gone, he having brought features in the distribution and mode of occurrence of these ores to notice, which required testing in a more authoritative way than usual, owing to the ground having been previously visited by Messrs. Medlicott and Mallet. I was greatly pleased to find that Mr. Bose was not only doing his work well and carefully, but that he had made observations and recognized features which will lead to a more qualified view of the manganese ore capabilities, as well as towards a further elucidation of the origin of that form of decayed, or methylosed rock, so well known as laterite.

Work of Sub-Assistants.

Messrs. Kishen Singh and Hira Lal were engaged during the last season, the one about Mandla and Seoni in the Central Provinces, and the other among the coal-fields in Chhattisgarh; that is, each of these Sub-Assistants is following up the areas or boundaries of formations already ascertained by the executive officers of the Survey. It is necessary to mention this, because, unhappily, Babu Kishen Singh has got it into his head that he is now on independent work, and so fit for promotion. It may be as well to state at once that this is not the case; as yet, he is certainly not fit to be set on new and independent work. This is however quite a different matter to the doing of the work he has in hand, which I am only too glad to praise as well and carefully executed. At the same time I should wish, as soon as the time may come round, to recommend that he, as well as Mr. Hira Lal, should be better remunerated for their work: this has already been strongly advocated by my predecessor, and at the first opportunity I shall press it again.

Mr. Hira Lal has the luck to be working at the coal-bearing rocks, and I think I have sufficiently expressed my liking for him and his work in that connection in my last paper on the Chhattisgarh coal-fields.

Both Sub-Assistants have sent in their maps, accompanied by fairly interesting and readable progress reports.

CENTRAL INDIA.
Mr. Hacket.
Mr. R. D. Oldham.

Rajputana has been for many years Mr Hacket's area, and he is still in it, working out details of the very puzzling and complicated relations of the several series or groups of transition rocks. Up to the close of last season his work lay in the neighbourhood of Mount Abu; but we are hopeful that his investigations may extend more to the westward, where he may be able to touch on the more economically interesting Gondwanas, with their coal possibilities.

As stated in Mr. Medlicott's last annual report, Mr. Oldham was occupied in testing his own suggestion of a possible occurrence of coal measures with coal in Jessalmer, though he was not very sanguine of success. It was, indeed, more of a scientific generalization than a suggestion, and hopes were high that success might

attend it; but so far the promise is not good, as will be seen in the memorandum published in the present number of the Records.

Extra Peninsular India.—Early last year, further evidence was sent in by Dr. H. Warth on the identity of the '*Olive Shales*' and '*Speckled Sandstones*' in the Salt Range geology. Mr. Oldham having been sent up in the previous season to settle the question, he was again despatched to the Salt Range to verify Dr. Warth's observations, which were published in the May part of last year's Records. The groups of rocks with boulder-beds at their bases, which have hitherto, in the eastern and western portions of the range, been considered, respectively, the one as of cretaceous, and the other as of upper palæozoic age, will now be merged in the name '*Speckled Sandstone*,' this group being, according to the latest utterance of Dr. Waagen, of the age of the upper coal-measures.

Mr. Oldham.
Dr. H. Warth.

Having finished his work in the Salt Range, which also included a visit to the Dandot Coal Mining operations, Mr. Oldham then proceeded to Simla, preparatory to making an expedition to Ladak and back by Kashmir, according to the desire of my predecessor, with a view to determining how far the discrepancies between the sequence of beds in Kashmir, as described by Mr. Lydekker, and that of the Simla region were real. On return from other work early in November, he was deputed to look up the prospects of obtaining petroleum at Tijarah, near Ulwar. His report confirms our original examination, *viz.*, that the bituminous stuff obtained from Tijarah is merely an occurrence of combustible organic matter in a thin layer, or seam, associated with potsherds and other refuse formed on the site of an old cattle village.

HIMALAYAS.
Mr. Oldham.
Mr. Middlemiss.

Mr. Middlemiss has been steadily pursuing his proper work in the lower Himalaya about British Garhwal and Kumaun, the results of which he is giving in a series of papers in the Records. His work continues to be excellent, and there is no lack in his enthusiasm and energy.

The Kashmir Government having applied for a geologist to look up and report on the occurrence and possible exploitation of the sapphires in the Zanskar district, Mr. La Touche was detached from his recess work in Assam. He was only able to work for a month at the locality, which lies just below the snow line, mainly driving an adit, or cutting through the great mass of débris which had fallen down over the old diggings, though without reaching the sapphire rock, and thus the examination is yet incomplete. Waiting a better opportunity for re-exploration when the retreat of the snow will permit, his services have been very advantageously employed by the Durbar in examining the Jummu coal, originally discovered by Mr. Medlicott, on which he is inclined to look hopefully, provided some method can be devised, similar to that adopted in Italy, for compressing the unfortunately crushed and powdery fuel into bricks.

KASHMIR.
Mr. LaTouche.

Sapphires.

Jummu Coal.

Mr. E. J. Jones was fully occupied until the end of the season in examining the principal coal-fields in Upper Burma, as well as the metalliferous mines in the Shan Hills, reports on which appeared in the last number of the Records.

UPPER BURMA.
Mr. Jones.

Survey Publications.—Part I, of the twenty-fourth Volume of the Memoirs, *viz.* :— "Southern coal-fields of the Satpura Gondwana Basin," E. J. Jones, was issued early last year: it treats of what is more generally known as the Chindwara coal-field. Volume XX. of the Records contains twenty-three papers, besides other matter, four of the articles being of important economic value. In series X, Vol. IV, Part III, of the Palæontologia Indica, Mr. R. Lydekker has described the "Eocene Chelonia from the Salt Range." It was to have been expected that the concluding part of Dr. W. Waagen's great volume on the fossils of the Productus Limestone of the Salt Range would have been issued, but an unforeseen delay has occurred through the copies of the last three plates, which were despatched from Munich long ago, having been mislaid in the carrying agent's office. Part IV, "Mineralogy," of the Manual of the Geology of India, by F. R. Mallet, was issued in July last: it forms a very fitting completion of the Manual.

Memoirs, Records, Palæontologia Indica, Manual.

Library.—Two thousand and twenty-four volumes, or parts of volumes, were added during the year; 1,270 by presentation or exchange, and 754 by purchase.

Museum.—Now that we have once more a Palæontologist on the Survey in the person of Dr. Fritz Nöetling, an endeavour is being made to bring the collections sent in from the field under thorough examination; particularly the *invertebrata*, which have in great part lain by so long, owing to the pressing necessity during Dr. Feistmantel's time for treatment of the flora of the Gondwana Formation, the lower division of which, it is perhaps hardly necessary now to mention, includes the Indian coal measures. Up to this time, Dr. Nöetling has been engaged in working out the *ammonitidæ* collected by Mr. P. N. Bose in the Bág beds of the Narbada valley, which, I am informed, corroborate in every way the original conclusions of Professor P. Martin Duncan regarding the Cenomanian age of these beds. The Silurian and other fossils, to be referred to in Mr. Griesbach's forthcoming Himalayan Memoir, are also being examined.

The Geological and Mineralogical galleries are in perfect order, the collections being gradually added to by presentations or by exchange with American, Continental, and British Societies and Collectors, notices of which have appeared in each part of the last volume of the Records.

Tours of the Director.—Notwithstanding the inconveniences referred to from time to time in his Annual Reports by my predecessor, among which are the having to rely on the carrying on of the current duties of the office by any Geologist who may be at hand, instead of a special Assistant as is the case with other Departments, and the editing of the publications of the Survey; I have been able to make three short tours. These were to the crushed-coal outcrops near Teendaria in the Darjeeling District; to the Karharbari coal-field; and to the Manganese ore deposits near Jubbulpore, the need for an authoritative visit to which I have already indicated when referring to Mr. Bose's work there.

WM. KING,
Director of the Geological Survey of India.

CALCUTTA,
The 31st January 1888.

Lis of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India, during the year 1887.

ADELAIDE.—Royal Society of South Australia.
BALTIMORE.—Johns Hopkins University.
BASEL.—Natural History Society.
" Basel University.
BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
" Royal Prussian Academy of Science.
BOLOGNA.—Royal Academy of Sciences.
BOMBAY.—Bombay Branch, Royal Asiatic Society.
" Marine Survey of India.
" Meteorological Department.
" Natural History Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
" Society of Natural History.
BRESLAU.—Silesian Society.
BRISBANE.—Queensland Branch, Royal Geographical Society of Australasia.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Royal Academy of Sciences, Belgium.
" Royal Geographical Society of Belgium.
" Royal Malacological Society of Belgium.
" Royal Museum of Natural History, Belgium.
BUDAPEST.—Hungarian Geological Society.
" Hungarian National Museum.
" Royal Geological Institute, Hungary.
BUENOS AIRES.—National Academy of Sciences, Cordoba.
BUFFALO.—Society of Natural Sciences.
CALCUTTA.—Agricultural and Horticultural Society.
" Asiatic Society of Bengal.
" Editor, Indian Engineer.
" Editor, Indian Engineering.
" Meteorological Department, Government of India.
" Royal Botanic Garden.
" Survey of India.
" The Calcutta University.
CAMBRIDGE.—Philosophical Society.
CAMBRIDGE, MASS.—Museum of Comparative Zoology.
CASSEL.—Verein fur Naturkunde.

CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Royal Danish Academy.
DEHRA DUN.—Great Trigonometrical Survey.
" Forest Department.
DELFT.—Polytechnic School.
DRESDEN.—Isis Society.
DUBLIN.—Royal Geological Society of Ireland.
" Royal Dublin Society.
" Royal Irish Academy.
EDINBURGH.—Geological Society.
" Royal Scottish Society of Arts.
" Scottish Geographical Society.
GLASGOW.—Geological Society.
" Glasgow University.
" Philosophical Society.
GÖTTINGEN.—Royal Society.
GRANVILLE.—Denison University.
HALLE.—Kais. Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.
" Natural History Society.
HARRISBURG.—Second Geological Survey of Pennsylvania.
HOBART.—Royal Society of Tasmania.
KÖNIGSBERG.—Physikalisch-Okonomische Gesellschaft.
LAUSANNE.—Vandois Society of Natural Sciences.
LEIPZIG.—Geographical Society.
LIÉGE.—Geological Society of Belgium.
LILLE.—Société Géologique du Nord.
LISBON.—Geological Commission of Portugal.
LIVERPOOL.—Geological Society.
" Literary and Philosophical Society.
LONDON.—British Museum.
" Geological Society.
" Iron and Steel Institute.
" Linnean Society.
" Royal Asiatic Society of Great Britain and Ireland.
" Royal Geographical Society.
" Royal Institute of Great Britain.
" Royal Society.
" Society of Arts.
" Zoological Society.
LYONS.—Museum of Natural History.
MADRAS.—Literary Society.
" Meteorological Department, Government of Madras.

MADRID.—Geographical Society.
„ Royal Academy of Sciences.
MANCHESTER.—Geological Society.
MELBOURNE.—Department of Mines and Water-supply, Victoria.
„ Geological Society of Australasia.
„ Royal Society of Victoria.
MILAN.—Royal Institute of Science, Lombardy.
„ Society of Natural Science.
MONTREAL.—Geological and Natural History Survey of Canada.
„ Royal Society of Canada.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Royal Bavarian Academy.
NAPLES.—Academy of Science.
NEUCHATEL.—Society of Natural Sciences.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
„ The Editors of the "American Journal of Science."
NEW YORK.—Academy of Sciences.
PARIS.—Geographical Society.
„ Geological Society of France.
„ Institute of France.
„ Mining Department.
„ Société Académique Indo-Chinoise de France.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
„ Wagner Free Institute of Science.
PISA.—Society of Natural Sciences, Tuscany.
ROME.—Royal Geological Commission of Italy.
„ Royal Academy.
ROORKEE.—Thomason College of Civil Engineering.
ST. PETERSBURG.—Geological Commission of the Russian Empire.
„ Imperial Academy of Sciences.
SACRAMENTO.—California State Mining Bureau.
SALEM, MASS.—American Association for the Advancement of Science.
„ Essex Institute.
„ Peabody Academy.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
SYDNEY.—Australian Museum.
„ Department of Mines, New South Wales.
„ Linnean Society of New South Wales.
„ Royal Society of New South Wales.
TORONTO.—Canadian Institute.

TURIN.—Royal Academy of Sciences.
VENICE.—Royal Institute of Science.
VIENNA.—Imperial Academy of Sciences.
„ Imperial Geological Institute.
„ Imperial Natural History Museum.
WASHINGTON.—Director of the Mint.
„ Philosophical Society.
„ National Academy of Sciences.
„ Smithsonian Institution
„ United States Geological Survey.
„ United States War Department.
WELLINGTON.—Colonial Museum.
„ Department of Mines, New Zealand.
„ New Zealand Institute.
„ Surveyor General, New Zealand.
YOKOHAMA.—Asiatic Society of Japan.
„ German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Natural History Society.

The Secretary of State for India.
The Governments of Bengal, Bombay, India, Madras, North-Western Provinces and Oudh, and the Punjab.
Chief Commissioners of Assam, Burma, and Central Provinces.
The Commissioner of Northern India Salt Revenue.
The Resident at Hyderabad.
The Surgeon-General, India.
The Quarter-Master-General of India, Intelligence Branch, Simla.
Foreign, Home, Public Works, and Revenue and Agricultural Departments.

Number of volumes and parts presented during 1887	1,270
Ditto purchased do.	754
Total .	2,024

Crystalline *and* Metamorphic Rocks *of the* Lower Himalaya, Garhwal, *and* Kumaon, Section III, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*—(With 3 plates.)

PART I.

BASIC LAVAS NORTH OF DUDATOLI.

In due order I must now sketch in brief outline some basic lavas and associated rocks which lie to the north of the Dudatoli area, and which occupy a large portion of the Syoons of Dhanpur, Ranigadh, Tili-Chandpur, Chandpur, and Nagpur Tala. As in the case of the acid lavas of Lobah, but little petrological work can be done in the field without the aid of the microscope to determine, in the first instance, what is the intimate structure of these, to the eye, absolutely compact and enigmatical rocks. It will therefore be necessary to follow the plan adopted in my last paper of very briefly describing the extension, lie, and general habit of the rocks as a whole, giving the results of the examination of numerous microscope slides in more detail. The whole of these notes will then form a body of data which will be a useful preliminary to the final description of the fully mapped area.

Like the ancient rhyolites of Lobah, these basic rocks belong to a geological system distinctly newer than the schists among which the gneissose-granite of Dudatoli is insinuated. The fault which separates the older and the newer series near Lobah, in its curve round the north portion of the Dudatoli area, similarly divides the rocks about to be described from the older Dudatoli schists. The discordancy in the dips, and in the nature of the rocks on each side of the faulted boundary, give it a great structural importance, and make it a striking feature both in the field and on the map. Its great extension, running as it does for 30 miles at least, proclaims it at once as a master-fault that has had no little influence in determining the present geology of this part of Garhwal. On its south side it leaves exposed the elongated quaquaversal synclinal of the Dudatoli schists, a long flat synclinal of great regularity—an oasis as I have previously termed it—among much more disturbed and highly tilted rocks, on to which we step when the faulted boundary is crossed. These newer lavas and other stratified deposits dip *away* from the Dudatoli centre in quite as marked a manner as the older schists dip *towards* that centre; and being only at present known on the north, north-east, and east sides of the older schistose area, they therefore form the north-east half of a quaquaversal anticlinal elongated in a direction north-west and south-east, and which, if completed, would cover in the whole of the present Dudatoli area, that is to say the ground represented on the map facing page 142, Vol. XX of this publication.

I must again refer the reader to that map, not for the purpose of giving at present a detailed description of the stratigraphy, but in order to roughly indicate the general positions of the rocks now to be discussed, and to give a connection, however superficial, between these notes and Sections I and II of this series. A few miles to the north beyond the limits of the map, but contained in sheet 14 of the 1 inch scale, from which the map is taken, the higher parts of the Dobri-Pandubri ridge are occupied by a massive limestone, an undoubted portion of the same rock as was des-

cribed in the Lobah area.[1] Only a small crescent of outcrop with the concave side towards the south has escaped the fault, but there is sufficient to shew that it overlies a purple and grey slate series with a suspicion of volcanic breccia among it closely resembling the purple slate and volcanic breccia series found in west Garhwal nearer the plains.[2] The horns of the crescent abut against the great fault, and outward from these points we travel over an ascending series of the volcanic rocks consisting chiefly of basic lavas and associated quartzites. Above the west-north-west horn, however, there is about a square mile of outcrop of the acid lava alluded to in my last paper and described microscopically by reference to a specimen, No. $\frac{7}{789}$, from the head of the stream running by Peera. Above it come the more basic lavas by gradual interbedding with, at first, a very large thickness of sedimentary rocks, *viz.*, purple and white quartzites and conglomeratic quartzites. Although the sequence here shews unmistakably the connection subsisting between the two volcanic series, and between those series and the massive limestone, yet it is complicated to a small extent by an inversion of the whole, so that the apparent dip in this one corner of the district is towards the south-south-east instead of in the opposite direction. This inversion is rapidly resolved within a radius of a few miles; as a traverse along the ridge towards Charmarguri trigonometrical station makes very evident: the purple quartzites and coarse grits rise more and more to the vertical and then fall again, but with an exceedingly high dip towards the north-north-west. They eventually settle down to a dip of about 70° in that direction. The limestone at Dobri and Pandubri trigonometrical stations is devoid of this complication: the angles are steep, sometimes even approaching 80°, but the dip, both of the limestone and of the superposed basic lavas and quartzites, is steadily towards the north. The intervening rhyolites are absent round the crescent of limestone in this neighbourhood, and they do not again make their appearance until Lobah itself is reached.

With dips radiating between the north-west and north-east, usually steep, but more so near the Ganges towards the north-west than along the Pindar river and round about Chandpur Garhi, these beds continue over the large area enumerated in the beginning of this note. The dip is, however, in many isolated cases in an opposite direction, and the same beds often seem to be repeated, either by faulting or by sharp flexure; so that there may not be such an immense thickness of them as would at first appear. Matters are also rendered difficult by a reappearance of the massive limestone near Limeri on the Pindar river. But as the stratigraphical details of much in this neighbourhood are at the present moment not worked out, further remarks on this head would be premature.

North of Sirobagar.—Several of the specimens next to be described agree in a way that can scarcely be accidental with those described by Col. McMahon from the Darang ridge,[3] and also with some from the lower Chakrata volcanic beds in Jaunsar, *viz.*, Nos. $\frac{6}{406}$, $\frac{6}{407}$, and $\frac{6}{408}$ from the Gam Gadh, collected by Mr. Oldham. The likeness is not altogether a superficial one, as will be seen from the sequel, so that, though I am generally averse to generalizing on petrological grounds, I cannot refrain from drawing the reader's attention to the probable contemporaneity of these three sets of lavas. It should be borne in mind, parenthetically, that the lower

[1] See Rec. XX, p. 162. [2] See Rec. XX, p. 34. [3] See Vol. XV, p. 155.

Chakratas are the oldest beds in Jaunsar, and that beds underlying the volcanic series in the district I am describing have at their base some splintery slates, grey and purple in colour and without a trace of schistosity, abutting against the Dudatoli schistose series. The regional metamorphism of the Dudatoli schists must therefore be attributed to a cause which acted before the younger slates, limestones and superposed lavas were laid down. Thus those schists belong to a very ancient land area; and even the subsequent intrusion or development of the gneissose-granite in them must date back to a geologically remote period, since the attendant garnets in the schists as previously shewn (Section II) were also anterior to the deposition of the upper portions of the younger series near Lobah, and contemporary with that of the ancient rhyolites.

The following specimens are from the cuttings in the road which runs from Srinagar to Rudarpraeg along the river. Taken together they form an important series illustrative of a structure constantly present in nearly every crystalline igneous rock that I have yet seen in this section of the Himalaya. I refer to the apparent foliation of the rock at its upper and lower surfaces. At one end of the series we have a massive compact rock, breaking independently in any direction after the manner of an ordinary trap. It is purple, or greenish purple in colour, and crowded in many parts with amygdules of red and white chalcedony, of dark green chlorite, of calcite, and occasionally of more than one of these substances together in the same amygdule. At the other end of the series we have a rock undistinguishable from a chloritic schist, of a pale greenish grey colour, slightly soapy to the touch and very fissile. It is almost as fissile as a slate, the dip of the laminæ being parallel with the dip of the beds. But the chief point of interest in the rock seen macroscopically is that there are several dark-green flakes covering the cleaved surfaces, and some few of chalcedony, which are nothing less than drawn out and pressure-flattened amygdules. Between the two extreme forms there are a number of intermediate ones shewing more plainly, and step by step, the transitions from the perfectly formed amygdules to the mere blotched remnants of them, flattened, drawn out lengthwise, and sometimes separated into shreds. Along with this change in the amygdules the rock itself becomes more fissile, and develops gradually a greener colour through the dissemination of the chloritic amygdaloidal contents (see diagrams I, 1, 2, and 3).

Taking into consideration the perfection of the transitional varieties in this series of specimens, it seems impossible to explain them except on the supposition of pressure and cleavage acting after the rock had assumed its solid form. For, it is to be noticed, the amygdules are composed of just those minerals into which a trap rock naturally changes through the alteration of its primitive mineral components, and the formation of secondary products. Chlorite, calcite and chalcedony are always due to secondary causes when present in igneous rocks—secondary causes which are not likely to have come about rapidly, and whilst the rock was still warm from its eruptive phase, but which are universally regarded as working slowly, *e.g.*, steady pressure in the presence of water or steam, but continued over a long period of time. Thus we seem bound to admit a primarily molten condition of the rock, full of vesicles which cooled and hardened; after this a gradual absorption of some of the mineral constituents and the re-depositing them in vesicles as chlorite, chalcedony, &c.; and

after this a pressure acting on the cold and solid rock which re-arranged the particles of the 'rock at right angles to itself, *in toto* producing cleavage and a spurious schistosity.

It should be noted here that the more fissile varieties are always next the outer surface of the bed, or set of beds, whilst the massive non-fissile rock is always near the centre, just as in the case of the gneissose-granite bands. The pressure foliation which I here advocate as the explanation in these basic rocks, I have, in a preceding paper, indicated as the possible explanation of much of the foliated and semi-foliated forms of the gneissose-granite; and further on I shall shew that a microscopical investigation of the Hansuri band bears out this view.

Specimen No. $\frac{7}{175}$, locality a little north of Sirobagar. Sp. gr., 2·75. Contains 56·91 per cent. of silica. This was the most massive, and the least altered by subsequent pressure.

Microscopical.—A very large portion of the ground-mass appears dark and unchanged under crossed nicols, indicating the presence of a glassy base or one very slightly altered indeed. The whole of the slice appears even darker in tint than the glass of the slide owing to the presence of a large amount of opacite in irregular minute grains. Thickly disseminated in the base is a sprinkling of microlites of plagioclase felspar, all radiating in different directions. They generally shew twinning, the twins extinguishing under crossed nicols very nearly parallel with the nicols and almost simultaneously; a very few larger micro-crystals of plagioclase dotted about the field shew it more markedly. This is characteristic of oligoclase. A faintly fibrous green mineral, probably chlorite, is irregularly intermingled with them, and has no effect on polarized light. It is also collected together in many of the amygdules, which are usually round or oval in section. In some pear-shaped amygdules containing this green mineral there is evidence of a slight general effect of greater darkening in certain directions when the nicols are crossed and the stage revolved, but generally they remain completely dark. There is no trace of micro-quartz in the slide, the only form of silica being the chalcedony of the amygdules. This appears rather to have been injected from a foreign source into the rock than to have been derived from the surrounding portions of it. There are no minerals belonging to the amphibole or pyroxene groups. The amygdules of chlorite may, it is true, represent material derived by alteration of one of these minerals; but from the large amount of viridite in the ground-mass, they may be merely segregations of that material which in itself never had the opportunity of crystallizing out in the form of hornblende or augite; in other words, as Col. McMahon suggests for the Darang lavas, the glassy base may have been partly altered into viridite. The most marked appearance in this rock-slide is undoubtedly the chalcedony. The amygdules of it are frequently encased in a thin layer of chlorite and calcite. A concentric zonal arrangement of the silica marks the growth lines within the original vesicle. Irregular cracks traverse the substance. On crossing the nicols the mass of the amygdule splits up into sub-angular portions, each of which shews a radiating or sometimes parallel streakiness of grey-blue and pale yellow colours, which darken in directions parallel with the crossed nicols when the stage is revolved, thus partially displaying a black cross. The zonal arrangement seen by ordinary light is always at right angles to the radiating structure seen in polarized light.

No. $\frac{7}{176}$. A dark greenish-grey compact rock, slightly fissile, the amygdules a

little flattened and drawn out. This specimen very much resembles $\frac{7}{778}$ being taken in fact from almost the same locality. The ground-mass is very slightly coarser and richer in microlites of oligoclase. The latter are longer and very slender, almost like hairs, and often collected in stellate or cruciform groups. The large amygdules shew no differences worthy of note except with regard to their included crystallites. These are larger and appear to be mulberry groupings arranged in rod-like forms as well as circular. The chlorite amygdules are very marked, each with a border of chalcedony. Another set of irregular lacunæ are filled by an intimate granular mixture of viridite and chalcedony. There is then no radiating but only a very fine granular structure under crossed nicols, the viridite having hindered the proper action of the spherulite-forming forces.

No. $\frac{7}{778}$. A greenish grey very fissile rock, the amygdules being completely drawn out into blotches. It is taken from near the same locality as the two previous specimens, but not far from the surface of the flow. It resembles them very much in its intimate structure, but the re-arrangement of the particles of the rock in parallel directions is as marked under the microscope as is the fissile character in the hand. The microlites of triclinic felspar are a little more ragged and kaolinised, and are not so sharp as in the preceding examples; still there is no clastic appearance whatever, no suggestion that it is an ash. The lacunæ full of chlorite appear teased out at their ends and amalgamated more or less with the ground-mass as also do the clusters of opacite. The slice has a general striped appearance in consequence. The teasing out of the opacite clusters is very characteristic, and perfectly resembles the spluttering caused by a bad pen.

No. $\frac{7}{779}$. A slightly coarser grained rock than the above, of greenish-grey colour, from the same locality. The amygdules to the eye have almost lost their individuality. The parallelism of some of the larger needles of triclinic felspar and of the opacite, and the thin drawn out shred-like edges of the green mineral where it fills lacunæ, all shew the foliated or cleaved condition of the rock perfectly well. Much of the green mineral in the ground-mass appears restricted in a more marked way than in any of the other specimens, as though, owing to the coarser nature of the rock, it represented the altered result of some previously half-crystallized mineral. Under the $\frac{1}{4}$ inch objective there can be seen numerous small fragments and aggregates of a greenish-yellow mineral. It is impossible to say whether these belong to epidote, which seems most likely, or to some form of amphibole or pyroxene.

Gwar and Biraon, along the ridge N. from Charmarguri trigonometrical station. —The first three specimens to be mentioned have a very general resemblance to those from N. of Sirobagar, but the remainder shew a gradual change into a completely holo-crystalline rock. The localities are within a few miles of one another.

No. $\frac{7}{780}$ *Biraon.*—It very much resembles No. $\frac{7}{776}$ from near Sirobagar. A good many of the lacunæ filled with chlorite are teased out in appearance and the arrangement of the microlites of felspar is somewhat parallel.

No. $\frac{7}{781}$ *Biraon.*—Under the microscope this rock presents a wavy, drawn-out aspect (not unlike flow-structure) of alternating layers of viridite and finely granular quartz, containing great numbers of twisted and broken microlites of oligoclase. The pale bright green layers of viridite under the $\frac{1}{4}$ inch objective have the usual fibrous, faintly linear arrangement, which so strangely mimics flow-structure in a glassy rock

that it is difficult to explain them entirely on the supposition that they are only drawn-out amygdules, and not part of the original glassy base altered into viridite. Probably the truth lies between the two. The granular quartz layers, however, are undoubtedly merely a further stage of a crushing out of the chalcedony amygdules, or rather of the less pure ones mentioned in No. $\frac{7}{776}$. Magnetite is present in large quantities, as clusters drawn out with the rest of the rock structure, and twisted into most fantastic shapes. Under the high powers it appears to be aggregations of very small four-sided figures. There is another mineral which cannot well be distinguished from the magnetite under the 1-inch objective, but which, under the $\frac{1}{4}$ and $\frac{1}{8}$ inch, comes out distinct from it. It is present in the form of irregularly circular or hexagonal figures, of dull olive-green colour and with no action on polarized light. With them are associated some very minute red garnets, so that it seems probable that the former are the melanite variety of garnet. Epidote in brightly polarizing grains and in short prisms is also present in very small quantities.

No. $\frac{7}{783}$ *Gwar.*—This specimen and the next to be described both shew a smaller amount of the original glassy base and a relatively more developed stage of the microlites of felspar. The present specimen is an aggregate of small micro-crystals of oligoclase in lath-shaped sections very well and strongly developed, but shewing a considerable amount of granular kaolinisation under polarized light, with feeble colours. They are set in a very small amount of base in which the opacite is scarcely separable. Lacunæ of chlorite, though of irregular contours, are very distinct from the base itself in which there is but little of the green mineral. There is no free quartz, nor are there any amygdules of chalcedony.

No. $\frac{7}{784}$. *Gwar.*—This rock is a fortunate link between the more eruptive character of the foregoing specimens and the more thoroughly crystalline forms to be described next. It is not composed entirely, either of large crystalline elements, or of microlites; but it is a porphyritic rock. The porphyritic crystals are large, frequently rectangular felspars, much altered into quartz of corrosion, but there are not many in the slide. There are also a few crystals intermediate between these and microlites, which often shew twinning, the angle of the hemitrope section giving between the two extinctions a value of about 38° in some cases, and lesser values in others. The porphyritic crystals, owing to their corrosion, are quite unrecognizable; the developed quartz granules not even polarizing concordantly. The microlites in the glassy base, which form the ground-mass, all shew extinction angles of the smallest possible amount, *viz.*, about 3°. Many are twinned, the twins extinguishing almost simultaneously. It seems probable therefore that the whole of these felspars are really triclinic and oligoclase. The rest of the ground-mass closely resembles that of Nos. $\frac{7}{775}$ to $\frac{7}{779}$.

No. $\frac{7}{785}$ *N. of Gwar.*—A finely holo-crystalline greenish rock. Sp. gr. 2·70. In the hand, and when a thin slice is held up to the light, it appears to be a mixture of felspar and some greenish mineral; but when it is applied to the microscope the felspar is discovered to contain quartz-pegmatoid and also quartz of corrosion (Fouqué and Levy); that is to say, the felspar has intergrown with the quartz to form the pegmatoid structure, and has been changed by infiltration of silica to form the corrosion structure. Very little of the original felspar is left in the latter case, but sufficient to be recognized.

In diagram I, 4 I have sketched an example of corrosion of the felspar, which very much resembles that figured by Fouqué and Levy,[1] but in the slide under description there seems to be an intermingling of this structure with the pegmatoid structure. The cuniform outlines of the quartzes in the felspar shape, which are sometimes Z-like, sometimes hexagonal or irregular, are fitted together at their angles and occasionally run into a vermicular radiating structure towards some point in the changed felspar. They always extinguish light under crossed nicols simultaneously in the same crystal of corroded felspar, that is to say, each of the semi-detached portions of the quartz have a connected crystalline structure as if they were figures stamped out of a single quartz. According to Fouqué and Levy the development of the quartz of corrosion must have taken place after the solidification of the felspar, and there seems no doubt that this has been the case here, for the original outline of the felspar is quite sharp and distinct as indicated by the edges of the corrosion quartz. Nevertheless triangular quartz sections joined to each other, apex to base (not seen in the diagram) in lines parallel or radiating towards a centre,— all of which structure is characteristic of quartz-pegmatoid—indicate simultaneous crystallization of felspar and of quartz. Since then these two structures are found together in the same rock melting into each other, though one may be a primary and the other a secondary structure, they must be nearly related. Possibly the latter followed very hard on the crystallization of the felspar; or the originally felspathic rock was sufficiently re-heated and charged with silica as to allow the molecules to re-arrange themselves into the pattern of quartz-pegmatoid.

A previously twinned structure in the felspar is indicated by the quartz of corrosion pattern polarizing in different shades on each side of the median line. The singly twinned felspars and the non-twinned felspars may be orthoclase, but it is difficult to say with certainty.

The remainder of the rock consists mainly of long, singly twinned prisms of dark greenish-grey colour under the 1-inch objective, but which under the higher powers shew as crystal outlines with minute grains of chlorite dotted about them. The few spaces of the field between and among the above mentioned minerals are occupied by chlorite, whose minute portions and fibrils polarize independently, giving a speckled or irridescent effect. Opacite abounds, in irregular grains.

This altered rock may have been originally a diorite or syenite; but it is impossible to say with certainty whether the felspar was orthoclose or not, and whether the greenish-grey prisms were originally hornblende or augite. On the whole, analogy would prefer to call it a metamorphosed diorite.

No. $\frac{1}{788}$. *N. of Gwar.*—A reddish finely holo-crystalline rock. Seen in the hand alone it resembles a diorite or syenite; but under the microscope, as in the previous example, the felspar appears changed into quartz of corrosion. There is also apparently some original granular quartz, not merely replacing the altered felspar. Quartz-pegmatoid structure is rare. The green mineral is altered beyond recognition into chlorite, but from the long prisms and by analogy it seems likely to have been hornblende. They are often long, singly twinned, dark grey, prisms, intact,

[1] Minéralogie micrographique. Planche XI, 2.

but having very little effect on polarized light. Opacite is present in grains and also in irregular blotches and pseudomorphs after replaced crystals of the unknown green mineral.

No. $\frac{7}{786}$. *Across the river opposite Limeri near Rudarpræg.*—A dark-green, coarsely granular rock with glistening crystals. Sp. gr. 3·06. It is perfectly holocrystalline, containing large lath-shaped prisms of felspar which remain uniform under polarized light, or darken so slightly, owing to their alteration, as to be undeterminable, by the extinction angles. There is a yellowish or greenish mineral polarizing in bright colours. Most of it, of a pale and cold tint is not dichroic and is much cut up by cleavage planes, which blacken and become wider in certain portions of the crystals. A broken octagonal section shewed three very distinct cleavages (see diagram I, 5), the most developed being parallel with the clino-pinacoid, and two others, nearly at right angles to each other, being parallel with the faces of the rhombic prism. The mineral is therefore diallage. Other sections of it shew it to be diallage or augite according as the clino-pinacoidal cleavage is strongly or weakly marked. The outer portions of some sections of this mineral shew a change from the cold yellow, which is not dichroic, into a warmer more greenish-yellow, which is highly dichroic. They also shew in parts the cleavage of hornblende. A hexagonal basal section, (see diagram I, 6), adjoining one of these hornblende borders shews the characteristic rhombic cleavage of that mineral, the angle measuring 123.° This section is strongly dichroic and extinction takes place under crossed nicols dividing the angle of 123.° The rock contains therefore both hornblende, and diallage or augite; and the first seems to be produced by alteration of the others. A further stage of alteration is reached by the production of chlorite, which in many cases replaces the whole of the green mineral and is invaded by blotched parallel lines of magnetite, which has been aggregated by infiltration along cleavage cracks. The chlorite is in fairly large, fan-shaped tassels, which polarize light in pale but brilliant colours. The felspars are the most perfect in shape and crystallized first. Then came the green mineral, which only very occasionally has a half-perfect crystalline form. Finally, there is a small amount of quartz, filling in the inter-spaces. It is never present in rounded grains or regular hexagons, but always in groupings suggestive of a secondary origin by corrosion. The irregularly shaped grains are roughly fitted together, but with thick dark bordering lines, and not in polysynthetic aggregation. They polarize simultaneously in groups, and in many respects resemble the corrosion quartz in Nos. $\frac{7}{786}$ and $\frac{7}{785}$, but they never so manifestly take the place of the felspars as in those rocks.

There are other small groups of a clear colourless mineral with a tesselated appearance which remain dark under crossed nicols. They must be tridymite. (See diagram I, 7.) Along with much of the chlorite and the secondary corrosion quartz just mentioned they fill up lacunæ among the other crystalline elements of the rock and are probably due to secondary causes entirely.

This is an interesting specimen in connection with those previously described, for it is the first having a holo-crystalline structure, which definitely shews what the original green mineral was which is represented in the more eruptive rocks by chlorite or some unrecognizable mineral. I will return to this subject after some few more rocks from a neighbouring locality have been described.

No. $\frac{7}{267}$ *Sonal near Dhanpur.*– A greenish-grey finely granular rock. It is olo-crystalline, composed of triclinic felspars in long blades, and augite in broken risms and a few basal sections. The augite is of pale greenish-yellow colour. It not dichroic, and the octagonal basal sections shew cleavage angles of about 84°. he prisms also shew angles of extinction at their sides in some cases nearer 30° ıan 20°. Thus there is no doubt that the mineral in this case is augite, and not ornblende. Only in a few places in the slide has the augite become altered at ıe edges into a much warmer, darker, dichroic mineral. This is no doubt a stage receding the development of hornblende. There is no chlorite in the rock at all. he polarization colours of the augite are very brilliant. The triclinic felspars are ıuch kaolinized and shew but little twinning and darkening under crossed nicols. s species cannot therefore be determined. There are a few irregular granular uartzes in the rock, but there is no corrosion-quartz certainly present. Opacite is resent in irregular grains and pseudomorphous after augite. The mineral composi- on of this rock taken in connection with that of the preceding one indicates that nong the whole spread of these basic lavas there are numerous passages between ıbbros, diabases, and diorites; and it follows that the hemi-crystalline represen- .tives of these which only contain the green mineral chlorite cannot therefore be ılled definitely either basalts or andesites.

No. $\frac{7}{213}$. *S. of Dhanpur.*—A greenish grey fissile rock. Under the microscope is composed of irregular layers of chlorite and granular quartz set in a still finer ıatrix of broken and crushed up material, cataclastic in nature perhaps rather ıan pyroclastic.[1] It seems to be a further stage of the crushing up of a flow, in hich the triclinic felspar has become kaolinized, and corroded, and rolled out, as were, under pressure into granular quartz interbanded with chlorite. Opacite is in regular grains and in long dusty clouds. The rock is therefore a chloritic schist hich represents the ultimate stage of alteration of the basic lava.

No. $\frac{7}{216}$. *Near Bhatkúwáli.*—An inky-purple coloured, finely cleaved rock. his is so often found associated near the edges of the undoubted lava flows that, ough it has all the appearance in the hand of being a slaty rock, it must, I think, : put down as a crushed igneous rock, the same generally as the last described. nder the microscope it is seen to be composed of a very fine clear granular matrix, :ry densely crowded with opacite in hazy clusters drawn out with the cleavage of e rock. When the nicols are crossed the ground-mass shews a very fine crypto- ystalline assemblage of little needles of felspar and other granular material of the ıest description. There is no augite or other green mineral. I cannot say definitely at it is not an ash, but I should incline rather to consider it as cataclastic than roclastic.

We may now sum up generally the whole of the evidence afforded by this basic ılcanic series, and see what results it leads to, and in what respects the rocks agree .th the Darang series.

(1) The flows are massive towards the centre, and foliated or cleaved at the up- :r and under surfaces. From the evidence of the amygdules these structures seem be due to pressure acting on the rock through long ages after it had cooled, and ɔt to be due (at least mainly) to differential motion of the particles by fluxion.

[1] Using the terms lately proposed by Mr. Teall, Geol. Mag. Decade III, Vol. IV., p. 493.

(2) The felspars in the eruptive phases of the rock are always oligoclase, clear, pellucid and twinned; and they grade upwards in size from very minute ragged needles to large microlites and micro-crystals, as the more holo-crystalline varieties are reached.

(3) The intimate structure of the foliated rock seen under the higher powers of the microscope shews as clearly as in the hand specimen its drawn out or cleaved condition by the parallelism of the felspar microlites, and the smudging out of the opacite, chlorite, and chalcedony. A final disintegrated condition of the felspar gives with the chlorite a simple chloritic schist.

(4) As the rock becomes perfectly holo-crystalline, the felspars appear (*a*) kaolinized, so as to preclude recognition by the polariscope; (*b*) changed into quartz of corrosion, with the same result; (*c*) in the pattern of quartz-pegmatoid.

(5) The green mineral in the more eruptive phases of the rock is always viridite with no action on polarized light; or some form of chlorite in fine fibrils or fan-shaped clusters, with positive action on polarized light; or occasionally epidote in minute quantities. No augite or hornblende have been detected in the rocks which possess a glassy or slightly altered glassy base. Probably much of the pale, clear viridite represents an altered condition of the base as suggested by Col. McMahon, but in many cases the restricted patches of it seem to point to a change *in situ*, from some pre-existent crystal of amphibole or pyroxene.

(6) In the holo-crystalline rocks we find the green minerals, augite, diallage and hornblende co-existing with felspars, kaolinized beyond recognition or changed to quartz of corrosion. We find opacite in pseudomorphs. Chlorite is rare along with augite, but the borders of the latter shew alteration into hornblende. Where both augite and hornblende are present chlorite begins to predominate. Diallage is present in some few specimens passing from or into augite. We seem to be driven to the conclusion, therefore, that the beginning of the green minerals in these rocks was as a chloritoid mineral and the final end of them the same. Those stages of the rock in which crystal-building was arrested by prompt cooling shew it in the ground-mass and also in lacunæ to the exclusion of other minerals; and the fully crystallized stages also shew it as the result of the breaking up of the other minerals.

(7) The Darang lavas described by Col. McMahon have therefore some points in common with these rocks as a whole, though not with any one in particular. In the first place they cannot be distinguished in the hand specimens, particularly Nos. 7 and 11 of his published series which shew slightly crushed amygdules. Next the large amount of viridite, or some form of chlorite is strikingly like the cases I have described. He has however found augite in the hemi-crystalline forms, whereas in this neighbourhood there is no unaltered green mineral present, save in those of holo-crystalline structure. With regard to the felspars, I think they are identical, at least in the more eruptive phases of the rock. Col. McMahon names the felspars of No. 1 of his Darang series labradorite, but in sections I had made of this rock and of No. 2 of the same set the microlites extinguished under crossed nicols at a very small angle with their sides, certainly not more than 3°, which is a characteristic of oligoclase. The almost simultaneous extinction of the twinned halves also bears the same interpretation.

(8) Owing to the evident change which has been induced in all these rocks by

permeation of acid waters, which has saturated them in places and left them intact in others, but little reliance can be placed on data derived from their specific gravities and percentages of silica.

(9) With regard to the stratigraphical classification of these volcanic strata, I can do little beyond throwing out a hint, that their wide extension, apparent great thickness, and general resemblance to the Darang and Bombay basalts, should make us look towards the corresponding great thickness of the lava-fields which form the Deccan in Peninsular India for their most likely equivalents. This would make them about cretaceous in age; and if the massive limestone which underlies them corresponds to the massive limestone which underlies the Tál beds in W. British Garwal, this conclusion is further warranted by the mesozoic age of the fossiliferous Tál beds.[1] There are some difficulties, however, in the way of this correlation—their possible equivalence with the Chakratas in Jaunsar being one—so that I do not think it worth while developing the idea any further at present.

PART II.

PINDWALNI ROCK.

I will now pass on to mention a rock which I am grouping next these basic lavas, although it is completely isolated from them, occurring in fact, among the Dudatoli schists, and although it is perfectly holo-crystalline and of a still more basic character than they. I have called it the Pindwalni rock, as it is exposed very near the village of that name distant $4\frac{3}{4}$ miles north 35° west from the north peak of Dudatoli (10,188 feet). I came across this rock loose in stream-beds many times before I could trace it to its home, notably as pebbles in the Chifalghat or west Nyar river near Paithana; in the Pindwalni stream; and in the small streamlet south of Bhalson opposite Bani Thal. *In situ* I eventually found it 2 miles south-east of Khand M., on the Chifalghat, and about ¾ mile south-west of Bhalson. It is there in the form of a thin dyke (30 feet?). Occurring in this region it is of interest as being very analogous to the so-called dolerite of the Chor, and I shall shew later on that its mineralogical composition is very probably almost identical with that rock, as described by Colonel McMahon.[2]

No. $\frac{7}{406}$ *near Pindwalni.*—A very dark greenish rock exceedingly tough and difficult to break with the hammer. Sp. gr. 3·01. Contains 40 per cent. of silica. The low percentage of silica in this rock and its high specific gravity prepared one to expect the presence of either anorthite or labradorite as the felspar representative. Under the microscope this is found to be the case, the rock-slice appearing as a holo-crystalline mixture of clear pellucid labradorite crystals, elaborately twinned and full of small crystallites; together with a pale yellow mineral, in small quantities; and a darker greenish mineral, generally decomposed beyond recognition into a chloritoid result. Titaniferous iron is also present. Taking the last mineral first for consideration, it is found largely represented either in irregular grains of opaque black material, or as skeleton trough-like forms, roughly hexagonal, with growth or decay lines crossing one another at angles of about 72° Among the six

[1] See Rec. G. S. I., Vol. XX, p. 34.
[2] See Rec. G. S. I., Vol. XX, p. 113.

sections, I had made of this rock, I found occasionally a bordering or striping of the mineral with a neutral tinted substance, which is probably the unknown leucoxene. Deep amber-coloured sphenes of small size are also fairly numerously dotted about in one section.

The other minerals in the rock are hornblende, very much altered; augite in small quantities; and mica, which last is only found in one section. The hornblende was for a long while undistinguishable, as several of the prepared slides shewed too much alteration of it into a chloritoid mineral. Eventually one of the sections gave a number of slightly dichroic brownish-green irregular forms, among which those with a prominent cleavage in one direction made extinction angles of 20° and under, with the cleavage; and one displayed a basal section with two sharply marked cleavages exactly at an angle of 124° with each other. Generally, however, the hornblende is so wholly altered as to have nothing but an aggregate effect on polarized light after the manner of radiating groups of chlorite. The augite is a very pale brownish yellow in colour shewing no dichroism. It possesses ragged outlines and is usually set in a mass of hornblende or altered hornblende. There were no sections characteristic of augite, but its scaly surface, numerous cleavage planes and brilliant polarization colours seem to indicate this mineral unmistakably. It seems extremely probable that the augite was the first and original green mineral in the rock, and that it was first altered into hornblende and that in turn altered into chlorite. Numerous sections bear out this view, for the cleavage lines in the pale nearly colourless augite run undisturbed into the dark brownish-green dichroic hornblende; although the minuter structure of the mineral, including its colour does not fade away from one to the other, but is very abruptly marked off (see diagram II, 8).

The most interesting mineral in the rock is the labradorite. It is coloured a pale warm drab of lighter and darker shades melting into each other. It occurs in very beautiful twins chiefly after the albite pattern, associated also with pericline twins. Carlsbad twins seem also to be combined with these in many cases, as indicated by the change in the direction of the indistinct basal cleavage on each side of the twinning line. Numerous examples of the albite twin when hemitrope in the zone at right-angles to the clino-pinacoid, shewed angles between the two extinctions on each side of the twinning line from 38° to 63°, the values 50°, 53°, and 55° predominating. In rectangular sections with two very distinct cleavages nearly at right-angles to each other there was once visible between the two hemitrope extinctions an angle of 62° which is the greatest possible for labradorite. There were none exceeding this so that the mineral cannot be anorthite. The polarization colours are blue-grey and pale yellowish-brown, and they have a very clear definition in nearly all cases. No kaolinisation whatever of the felspar has taken place, except as exhibited in one section, where curiously the hornblende is better preserved than usual.

A striking feature in the labradorite is the innumerable small clear crystallites which throng it. In most of the plagioclase sections they seem arranged as irregularly as a pack of cards thrown on the floor, but in some few they are gathered along definite lines either parallel with the sides or the cleavages of the labradorite. They are clear, pellucid and colourless, and possess a fine, but distinct outline. Their

shapes are slightly elongated prisms, rhombs, hexagons, and rectangles (see diagram II, 9). Some appear to have no action on polarized light, others have a feeble action, the colours being pale blue-grey and yellow, but quite independent of those of the labradorite in which they lie. In some cases they are scattered sparsely, and in others they are packed into dense masses so as to slightly obscure the natural appearance of the felspar. They shew no internal structure such as cracks or cleavage. They do not stand out with the characteristic relief, nor have they the jointed appearance of apatite: some few long, jointed prisms of apatite, actually present in the slide, rendering this contrast the more striking. They are entirely confined to the felspars and may probably be tridymite, developed along the cleavage planes, after a habit which tridymite is known to affect. The presence of undoubted tridymite in slice No. $\frac{7}{187}$ lends support to this idea, and favours the theory of its secondary origin.

There is no free quartz in the rock-slice as would be expected from its low percentage of silica: a percentage which also makes it difficult to understand even the presence of the tridymite, although doubtless the thinness of the shapes prevent their aggregating very much. In this connection its presence at all in such rocks as the Limeri rock (No. $\frac{7}{187}$) is remarkable, as it is generally wanting in all basic rocks.

I have not seen anything that I could with certainty call olivine in the rock. One or two small isolated pale minerals which I have classed with the augite may possibly be olivine, but I am inclined to think that it is altogether absent.

The specific gravity of the rock: the peculiar colour of the felspars which cannot be resolved under the higher powers of the microscope into any thing more than a faintly striped appearance: their regular shape: their belonging to the labrador species: the irregular ground-work of augite and hornblende in which they lie: the clearness of the twins, and the forms of the twins: the forms of the black mineral in large decomposed or replacing crystals, and the change of it partially into leucoxene, all seem to correspond in a marked way with the described structure of the dolerite of the Chor.[1] The main difficulty in the way is the apparent absence, in the specimens from the latter place, of the supposed tridymite in the labradorite. Still that mineral may be the effect of local schillerization in this particular area.

This Pindwalni rock, as I have already mentioned, is typically perfectly massive without any parallelism among its parts. At its upper and lower surfaces however it becomes foliated in the same way as the gneissose granites and the basic lava flows do. It was unfortunately impossible to obtain a specimen of the foliated portion *in situ* for slicing sufficiently undecomposed, so that the next specimen to be described had to be collected in the stream-bed south-west of Bhalson. As this stream is very small and the Pindwalni rock crops out in its upper part, I think there can be no reasonable doubt that it is really derived from the same bed as the Pindwalni rock, but at one of its surfaces. In addition it may be mentioned that the ordinary Pindwalni rock was scattered about in the stream in the immediate neighbourhood.

No. $\frac{7}{188}$. *Stream south-west of Bhalson.*—A black and white foliated rock. Under the microscope it is seen to be very well foliated indeed, and to consist largely of layers of quartz and felspathic material interbanded with layers of a decomposed greenish

1 See Vol. XX, p. 114.

mineral either hornblende or mica. Eyes of felspar are seen much drawn out, crushed and corroded, so that they have a granular appearance especially towards the drawn out ends of the eyes. Under the ¼ inch objective by ordinary light this corroded or crushed structure is invisible, but there is seen on the other hand very prominently a number of included clear crystallites of exactly the same shape and arrangement as in the felspar of the Pindwalni rock. The crushing and corrosion of the felspar has of course obliterated all signs of twinning.

A very marked feature in this rock is the black mineral which is in irregular grains surrounded by quite a thick border of leucoxene of dark neutral grey colour, shaded towards the borders, and with a faint aggregate polarisation.

PART III.

SCHISTS AND GNEISSOSE-GRANITE NEAR HANSURI.

I now pass on to describe a few typical specimens taken from the schistose series and gneissose granite on the south side of the Dudatoli area. In section I of these papers I gave a general idea of these rocks viewed macroscopically, and a more circumstantial account of their field relations. The following notes will therefore strictly concern their structure under the microscope.

No $\frac{7}{808}$. *Stream below Kainur.*—Garnetiferous mica-schist of the most thoroughly crystalline type. Under the 1 inch objective the mass of the rock is seen to be made up of clear quartzes polarizing in very clear and fairly vivid colours. They have the usual granular structure belonging to a thoroughly crystalline schist, that is to say, the grains with irregular outlines, only sometimes visible by ordinary light, shew, when the nicols are crossed, intricate, curved boundaries between differently coloured crystalline portions. The quartz layer as a whole is traversed by very many irregular cracks which cross from one to another of the differently polarizing grains. There is thus no residual sedimentary structure visible, no worn grains suggesting an original deposition by aqueous causes: or in other words the quartz must have been at the period of its metamorphism in such a state as to allow free play for the molecules to arrange themselves into crystalline portions, the formation of one portion being only interfered with by the formation of its neighbour, or by the other crystalline ingredients in the rock.

The mica of pale brown and brownish-yellow colours is seen distributed in plates and irregular grains generally parallel with the foliation. They shew no cleavage. White mica is also present running in long lines and possessing a very noticeable cleavage.

Sharply marked off from the other constituents of the rock are the garnets which are pale claret coloured with a very well marked raised outline. Their forms are irregular polygons, generally more or less rounded. They are perfectly intact without any breakings or tendency to be drawn out or cracked, as in the case of the St. Bernard rock. In this respect they differ entirely from the garnets present in the "gneiss-granulitique" of the snowy range at Kedarnath, which are of a ragged, shred-like aspect as though merely filling interstices among the other minerals. The garnets are of several sizes, though there is a general uniformity in this respect among the majority of them. A few very minute ones are just discernible under high powers (¼ and ⅛ inch objectives). Within each of the larger garnets, which is of course

dark under crossed nicols, there shew up a large number of irregular cavities and included portions of other minerals. Towards the centre of the garnet these are quite dense, whilst the outer border of the garnet is quite clear. The cavities are chiefly gas cavities of oval, lenticular, and irregularly amœbiform shapes, only rarely shewing polygonal outlines approximating to the shape of the garnets, and herein differing again from the rocks at Kedarnath in which the garnets shew this structure conspicuously. The gas cavities are distinguished by their black borders which shade away gradually. There are other irregular inclusions devoid of crystalline shape which shew feeble colours under polarized light, and must consequently be some included crystallite. Opacite in irregular strings and blotches is also included with them, and occurs nowhere else in the rock. Some few inclusions with a fine outline seem to be of an aqueous nature.

Besides quartz, mica, and garnets, there is another fine fibrous mineral, clear and of pale yellow or greenish colour, arranged in brush-like aggregates and polarizing vividly under crossed nicols. The brushes of this mineral run among the other constituents of the rock. The fibres are long and rod-like, often divided across by cracks, which split them up like the usual forms of apatite or of bacteria. It is probably sillimanite. Doubtless it and the garnets and much of the mica were the last result of the metamorphism induced by the gneissose-granite of Dudatoli.

No. $\frac{7}{808}$. *From near the same locality as No.* $\frac{7}{806}$.—Whilst the latter represents more definitely a foliated richly garnetiferous schist, the present specimen is from a more arenaceous band. Under the microscope it very much resembles No. $\frac{7}{806}$ the quartz and mica being in very much the same condition except that the white mica is scarcer. The large garnets are absent, but there are a number of very minute ones in different parts of the field.

There is one mineral of faintly olive-green colour and rather dichroic, changing from a brownish to a bluish green, which under crossed nicols appeared to extinguish light only twice in a complete revolution of the stage of the microscope, *viz.*, when the long axis of the mineral, which was rod-shaped, was parallel with the horizontal nicol of the analyser. They were very small, but there were several examples in the rock-slice.

There is also another unknown mineral ramifying about in cob-web fashion, without any distinct structure, among the quartz grains. It did not seem to be perfectly isotrope, although in ordinary light it much resembled an imperfectly built garnet. Its nature I could not determine.

No. $\frac{7}{816}$. *Pokree E. Nyar R.*—This mica-schist resembles the other two specimens of this series except that it is much less well pronounced as a schist and finer grained. It has a smaller amount of mica in minute irregular grains, without crystalline outlines or cleavage, and brownish-green in colour. There seem to be no white mica and no garnets present. The quartz grains do not polarize in rich bright colours as before, but in more neutral tints, blue-grey and faint orange predominating, purples and reds being rare. Under the $\frac{1}{4}$ inch objective rod-like belonites of pale green colour are fairly numerous, and some few doubtful minute bodies which may be proto-garnets, but they have no decisive action on polarized light.

No. $\frac{7}{813}$. *Hansuri band of gneissose-granite.*—In section I, I described this rock macroscopically classifying it with the lenticular-tabular variety of the gneissose-granite. In briefly commenting on the structure I then said:—"I by no means imply

that the lenticular-tabular is necessarily an embryonic condition of the augen. It seems as likely that the reverse is the case."[1] I think I can now shew by the aid of thin slices of this rock and of the quartzite near Rudarpraeg that this lenticular-tabular structure is due rather to the coalescing by crushing of originally separate crystals of felspar and grains of quartz than to an attempt at the formation of individual crystals and grains from the primarily structureless folia. It is of the greatest importance to establish the right order in this phase of rock-structure, so as to give a rational basis for an opinion concerning the date of the foliation which has happened to nearly every crystalline rock in the Himalaya; the more so because this structure has recently been differently interpreted, and assigned as largely contemporary with the intrusion of the gneissose-granite and due to fluxion rather than to subsequent pressure. The evidence which I shall give here, and that already given in the case of the amygdules of the Sirobagar lava-flows, leaves, however, no doubt in my mind that it is a super-induced phase, having no reference to flow-structure, and which may have happened at any time subsequent to the cooling and consolidation of the rocks in which it occurs.

The first section I had made of this rock shewed the peculiarities represented in diagram II, 10. I examined it first by the eye with reflected light alone, in a fairly thick slice, and then with the hand-lens, and was able to make out the following:—A and B represent two crystals of orthoclase in the shape of eyes which are united together by a connecting portion *xy*, forming altogether the prevailing lenticular-tabular structure. When the light was allowed to fall obliquely on the rather thick section, the twinning of the two felspar eyes was most manifest. The portion *a* was more illuminated than *b* and *a'* than *b'*. The bridge *xy* shewed no twinning nor extra brightening of the felspar: it had a rough and crushed look. Thus although superficially the felspathic layer seemed homogeneous along its whole course, this experiment shewed that there was a radical difference between the eyes of felspar A and B and the felspathic material *xy*, such a difference as would be implied by two original crystals A and B having been crushed into each other or over each other, the debris of the crushing going to form the bridge *xy*.

Seen under the microscope the evidence is amplified by the greater power of detecting the individual portions of the felspar which have become detached from the original crystals, and which lie embedded amongst granules of quartz. The crystals of felspar present a very much dappled and altered appearance, but they shew characteristic cleavage and polarize in their different tints as a whole and display twinning on the Carlsbad pattern. They are thus sharply marked off from the debris of quartz and felspar which fills in the bridge *xy*. It is thoroughly seen what a ragged, broken edge the felspar has, how it is torn into shreds and mechanically corroded, worse than a crystal of quartz or felspar in a rhyolite. Any one examining this rock and observing how the complicated and beautiful structure of the felspar has been battered and buffeted, would be as incapable of believing that a granitic rock was being evolved under these conditions, and that felspar was being aggregated into orderly crystals out of this chaos of remnants, as he would be on seeing the fragments of a beautiful vase of imagining that they were the constituent elements out of which such ornaments were ordinarily made.

Diagram III, 11 represents a portion of this rock as faithfully as I can reproduce

[1] Vol. XX, p. 139.

with the means at my disposal. It is seen to be built up of layers of quartz and mica besides the lenticular-tabular felspar folia. The former constituents do not differ much in their arrangement from those in the mica-schist described from below Kainur. There are no garnets and but little opacite in the rock.

Thus, taking into consideration the fact that through the whole of the structural varieties of the gneissose-granite we have passage forms connecting the tabular-foliated with the perfectly granitic form; and that between two of this series, namely, the lenticular-tabular and the augen, the order of development has been demonstrated to be from the augen to the lenticular-tabular, we may provisionally accept as true, until the opposite is proved, the general statement that the foliation of the gneissose-granite is a structure induced on a normal granitic rock by movements of the particles of the rock over one another causing them to be crushed and their crystalline contents to be disfigured and distorted.

But it may be argued that this crushing and distortion may have taken place under half-molten conditions of the rock: it may be said that the evidence I have offered shewing differential motion of the particles of the rock would apply quite as plausibly in explaining flow-structure in a rock which contained partly solidified crystals: it is perfectly true that I have given sufficient reason for thinking the tabular-foliation to have arisen from an originally granitic state, but I have not shewn that this did not come about as Col. McMahon thinks[1] by immediate transformation of the imperfectly consolidated granitic paste into a foliated substance, by a movement akin to flow-structure having been set up in it in consequence of its having been forced into fissures among the bedded schists. In other words it is still necessary for me to shew that this crushed and foliated structure was induced on the rock *in the cold*, as a later production, perhaps a geological age subsequent to the original development of the granite. With this end in view I will describe microscopically a lenticular-tabular quartz-schist previously quoted by me in Vol. XX, p. 139.

No. $\frac{7}{799}$. *N. of Rudarpraeg.*—This quartz-schist in the hand specimen can be seen to be composed of grains of quartz without any felspar or anything that would suggest an igneous origin. Moreover in some places there are pebbles, perfectly rounded by water-action as large as a hen's egg. No one would be inclined to doubt that this rock was a metamorphosed sedimentary rock. Under the microscope it is seen to be composed of lenticular-tabular layers of quartz and finely powdered quartzose and argillaceous material, with very thin streaks of micaceous material bordering the lenticular-tabular layers. These layers are seen to be composed essentially on the same plan as those in the gneissose-granite of Hansuri, that is to say, eyes of quartz form the expanded portion of the layer and fragments of the same mixed with argillaceous material bridge over the interval between the two (see diagram III, 12). The quartz under the microscope seen by polarized light is of uniform colour or of two or more colours watered into each other over the greater part of its section. But towards its borders it becomes surrounded by several rainbow halos, which become less bright as they merge into the finer material of the rock. A striation following the foliation of the rock runs the pointed ends of the eyes into the finer material gradually merging them into one another. We have the following stages manifestly indicated by the present rock-slice: (1) an original

[1] See Geol. Mag. May 1887, p. 212, and Rec. G. S. I., XX, p. 205.

approximately spherical condition of the grains of quartz; (2) a crushing and breaking up of portions of them, which are left *in situ* just as they were torn away from their parent grain; (3) a further pounding up of some of the fragments and a merging of them into the finer material of the rock; (4) a coalescing of this broken and powdered material with each end of a rounded grain of quartz to make an eye, and the concomitant development of the films of mica separating the lenticular-tabular layers.

I think no one will doubt that in the case of this rock the development of a lenticular-tabular foliation, exactly similar to that in the gneissose-granite band, has taken place *in the cold*. The only other alternative would be to accept a quartzite containing well-marked rounded grains and still larger pebbles, as a kind of igneous rock. As that alternative is impossible we must take it as proved that both structures have been produced in the cold and solid way.

In the earlier part of this paper I shewed that the foliation of the basic lavas near Sirobagar had, from the evidence of the drawn-out amygdules, been similarly accomplished since the rock had cooled and solidified. We have therefore instances in this part of the Himalaya of plutonic, volcanic, and sedimentary rocks, all having suffered this peculiar form of foliation. In other words, each of the great representative rock groups have been influenced by it impartially. We must therefore look for a far-reaching cause for this structure, and as we have seen that that cause must have been pressure resulting in crushing, we must invoke a universal pressure as the all-powerful agent: and the only universal pressure that we know of is that involved in the earth-movements which have been at work for ages building the Himalaya ever higher and higher.

REFERENCES TO PLATES.

Diagram I, 1, 2, 3. Illustrating the drawing out into shreds of the amygdules by pressure after consolidation in the Sirobagar basic lavas.

Diagram I, 4. Quartz of corrosion structure in altered diorite or syenite, from near Gwar.

" " 5. Diallage in gabbro, shewing characteristic cleavages in basal section from near Limeri.

" " 6. Basal section of hornblende in same rock, shewing characteristic cleavage at 124°.

" " 7. Tridymite in the same rock, filling a cavity along with radiating chlorite.

" II, 8. *a*=augite changing into *b* a dichroic hornblende-like mineral. *N.B.* the shading in b is not intended for cleavage lines.

" " 9. Tridymite (?) crystallites developed in Labradorite of the Pindwalni rock. *d*=a massing of the crystallites along a cleavage crack.

" " 10. Lenticular-tabular structure as seen by the eye alone in a thin slice, Hansuri band of gneissose-granite: for reference see letter-press.

" III, 11. The same rock under microscope with crossed nicols. References the same as in 10. *e*=mica layers; *d*=quartz layer.

" " 12. Lenticular-tabular structure in quartz-schist near Rudarpraeg; with crossed nicols.

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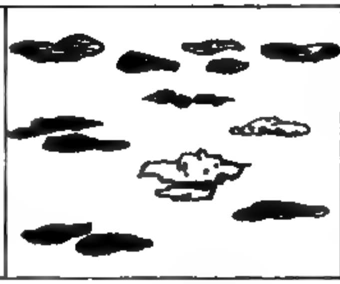

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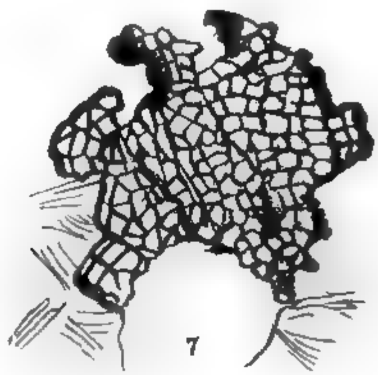

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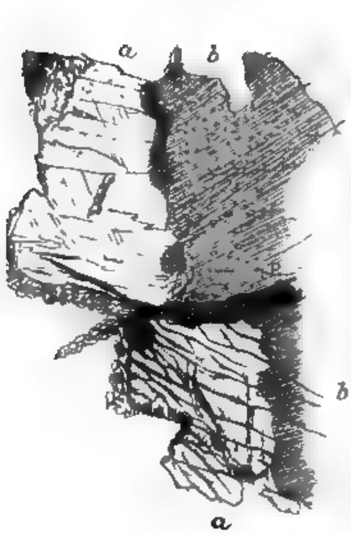
DIAGRAMS I.



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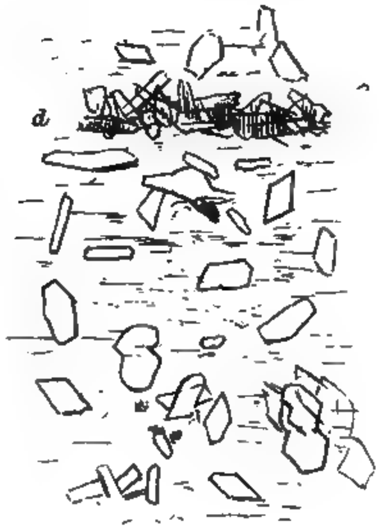

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DIAGRAMS II.

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DIAGRAMS. III

The Birds-Nest *or* Elephant Islands, Mergui Archipelago. *By* Commander ALFRED CARPENTER, R.N., H.M.I.M.S., *S.S.* "*Investigator.*"

This remarkable group, called by the Burmans Ye-ei-gnet-thaik (lit. sea birds' nests) is located on the south-east side of Domel Island one of the largest of that chain forming the Mergui Archipelago at the southern extreme of British Burma. It is a small group of 6 marble rocks, the highest and largest of which, 1,000 feet in altitude, and about one mile in length, is oval-shaped and rises very abruptly out of a depth of only 5 fathoms.

They present a very striking appearance, particularly if the weather is hazy, when they are not seen until within five or six miles; for then they gradually loom out through the mist like some huge mishapen monsters that have strayed away from civilization.

Their sides are partly clothed with vegetation wherever a break in the limestone has left a cleft in which moisture and dust can lodge. Conspicuous because of its leaning attitudes is a species of tree fern which appears content to grow at any angle, but only above a height of 200 feet from the water.

The face of the rocks is reddish, partly from weather and partly from soil; and where cliffs exist the most beautiful though uncouth stalactitic formation is at work, hewing grotesque and snake-like patterns varying in hue and shape, till one feels as in some ogre-enchanted land. But the great feature of the group are the birds nest caverns which, as a rule, open into the sea, the entrance being below high water mark; fortunately I visited them at spring tides and had plenty of leisure to examine each cavern in two days' low waters.

At the south end of the largest island stands a ninepin of grey marble, 370 feet high, almost separated from the rest. It is hollow like a huge extinguisher, and the polished light blue and light yellow sides of the interior seem to point to its having been hollowed by the swell of the sea, which on entering the cave would probably expend its force vertically, the mouth of the cave being open to the direction of the strongest seas.

This ninepin forms the western point of a nearly circular cove 360 yards in diameter which runs back into the big island, and the sides of the cove rise steeply though not perpendicularly from it. At the head of the cove is a perpendicular wall of rock over which can just be seen the 1,000 foot summit in the distance.

At half tide a tunnel opens under the wall of rock at the head of the cove, and a canoe can go through; but it requires to be within an hour of low water springs for a ship's gig to go through. This tunnel has a roof-covering with large stalactitic knobs, except at its narrowest part where it is apparently scoured smooth by the action of the tidal rush. It is about 250 feet long and 4 feet deep at low water, the rise and fall being 16 feet, and is covered with dripping marine life, corallines, small corals, comatulæ, sponges, and sea-horses. Passing through this submarine drain one emerges into another circular basin with perpendicular sides, which gives the impression of volcanic action, so like it is to a crater. This basin is only open to the sky; caves here and there open into it, some of which may perhaps lead by long tunnels to other basins. Water was running freely into it from the foot of the cliffs

in several places as the tide fell, shewing that water-spaces existed, and strange gurgling sounds, as of air taking the place of water, could be heard now and again. The first thought that strikes a European is "what a famous place for smugglers." There were hardly any signs of the place being utilized, except here and there the worn ropes of birds' nest climbers. It was either not the season for the swallows or they had deserted the islands, for none were seen. There was a little reddish guano in some of the caves. There was evidently but little traffic through the tunnel by which we entered, for the delicate growth on its sides was hardly injured.

On the west side of the northern large island a lofty cavern opens at half tide into another nearly circular basin of about the same size as that we have just described, but in this case the basin also opens into the sea on the east side of the Island. After contemplating the cliffs that surround these basins, and the general circular contour of the high ridges of these islands, and the undermining action of the sea at the water line, causing in some places an overhanging of 20 to 25 feet, and the softening of the marble surface of the cavern roofs by moisture; the impression gradually forces itself on one that these circular basins were themselves at one time the floors of huge caverns, and that in days gone by the islands were far higher, with cavern piled on cavern, and that the work of disintegration by moisture is slowly going on, pulling down these marble monuments of a giant age.

Indeed, here and there a fall of blocks has occurred lately, and from there being no shoal off the base of the slip the dissolving action, if such really occurs, must be rapid.

A small oyster covers the rocks at the water line. A handsome kingfisher was secured and sent to the British Museum. A few doves and an eagle or two were the only other birds seen, besides a small bat in the caves. By the position of the nest seekers' ropes, the swallows appear to build only on the roofs of the caves. The Islands appeared to be entirely composed of a blue tinted marble.[1] A vessel could be alongside them and lower the cut blocks straight into her hold, but it is probably of too poor a quality to be worth shipment.

Memorandum on the results of an Exploration *of* Jessalmer *with a view to the discovery of* Coal, *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.*

1. On taking up work I marched in the first place to Báp and commenced an examination of the country in that neighbourhood and to the north. I found that the boulder beds cropped out to the west of Báp, extending further in that direction than I had thought probable, and that they are there associated with a great

[1] Two specimens of the limestone have been sent to the Museum by Commander Carpenter; they are a very pure pale grey-coloured massive sub-crystalline carbonate of lime: in fact a marble, which if obtainable in fair-sized pieces would do for use or ornament where the colour is not objectionable, as for flags, wash-hand stand and table top.

development of dark red clays and shaly sandstones for the most part impregnated with salt.

2. To the northwards I traced the boulder beds as far as the limit of Jessalmer territory, beyond which they do not appear to crop out at the surface; and to the southwards I believe I have traced their utmost extent.

3. As remarked in my former memorandum,[1] this country is very unfavourable for geological observations, but I had no conception of how impossible it is to make a satisfactory detailed geological map until I had made the attempt. In the immediate vicinity of Báp and the Sird villages there are stream beds which do to a certain extent exhibit the rocks, but for the rest there is nothing but a vast undulating plain of sandy soil in which the underlying rock is represented by patches, varying in size, of pebbles, fragments of ferruginous sandstone or of concretionary limestone. Under these circumstances it is impossible to satisfactorily determine the true relations of the rocks, but one or two points stand out with some clearness.

4. First among these is the fact that wherever the rock immediately overlying the boulder beds is seen it is a hard, black ferruginous sandstone, with or without pebbles; it might be supposed that this indicated a conformity between the boulder beds and the ferruginous sandstone, but it may be, and probably is, merely due to the fact that, except where hardened by impregnation with iron, the sandstones do not shew themselves distinctly at the surface. Under these circumstances there is no proof that the different exposures of the black sandstone represent the same horizon, and it is by no means impossible that the boulder beds are unconformably overlaid by sandstones of upper gondwana age.

5. In the neigbourhood of the village of Akhádaṇa there are some indications that such is the case. Here there are some low, rounded ridges, covered with shingle, in the hollows between which the boulder-bed is exposed. The matrix of the conglomerate from which the pebbles are derived is not as a rule to be seen, but, where this is a sandstone of the black ferruginous type, it occasionally crops up through the surface wash of shingle and the transition from the boulder beds with numerous large unrounded fragments of red syenite and malani porphyry to the conglomerates, in which these rocks are barely represented and then only by small rounded pebbles, is so abrupt as to suggest an unconformity.

6. If this be so, there will be but little use searching for coal in this neighbourhood, and there is another fact which points to the same conclusion. At Akhádana a well has been sunk which originally reached a depth of 380 feet but is now nearly filled up; to judge by the debris excavated, this well appears to have been sunk through red sandstones of Vindhyan type with the exception of some 70 feet or so (14 *purus*) which was in pebbly sandstone; but as the well is lined with masonry throughout the portion still open, I was compelled to trust to native information and an inspection of the waste heap.

7. This indicates that the very irregular junction of the Vindhyans and newer beds noticed further east extends for some distance to the west, and any borings put down here would be more likely to strike Vindhyans than coal, at a moderate depth.

[1] R. G. S. of I., XIX, p. 122.

8. I made a short tour into the sandy desert towards Bikampur in order to see whether the rocks exposed in the wells gave any indication of the presence of coal measures: though I visited two wells in course of construction, I was not fortunate enough to find any deposit, and the rocks were all of a type very similar to those seen among the upper Gondwanas of Jessalmer.

9. Having examined this district sufficiently to see that no promise of coal could be obtained, I marched towards Jessalmer, intending to visit the reputed coal of Hamira and then to the unknown country south of Jessalmer. The so-called "coal" of Hamira I found to be merely [illegible] trunks and fragments of fossil wood in which the structure was still quite distinct; owing to its lightness and the abundance of pyrites this would be of very little use even if it occurred in quantity, but owing to its mode of occurrence as fragments scattered through a sandstone matrix it is quite useless.

10. To the south of Jessalmer I found a descending series of sandstones, in the upper portion of which hard ferruginous bands and patches were abundant, extending as far as Devikot. To the south of this the beds must turn over, for at Vinjorai ferruginous sandstones again appear and form prominent scarps, here however with a southerly dip.

11. The rocks near Devikot are, for the most part, a red sandstone, not unlike some of the sandstones near Nagore, but the frequent occurrence of spherical concretions, the general softness of the rock and above all the occasional occurrence of hard ferruginous bands leave but little doubt in my mind that they belong to the Gondwana series. It is impossible to say whether the red colour is original in the rock or merely due to its being formed of the débris of the presumed Vindhyan sandstones: if the former be the case it may indicate the proximity of the red rocks associated with the Bap boulder beds.

12. Hearing that rock was exposed in many places along the eastern frontier of Jessalmer south of the Jessalmer-Pokran road, I examined these outcrops which proved to be nearly all conglomerates and sandstones of unknown age, but as the crystalline rocks appear to be nowhere far from the surface and repeatedly crop out, it would under any circumstances not be advisable to put down borings on this line of country. To the west, rocks are said to be all hidden by sand until the exposures between Jessalmer and Vinjorai are reached.

13. From Jessalmer I crossed over to Pokran to try what might be found there, and was somewhat surprised when a detailed examination of this tract convinced me that the boulder beds there pass under the dark red sandstones which have been regarded as of Vindhyan age. There is no direct proof of the age of these sandstones, nor was I able to determine whether the boulder beds of Bap and Pokran were the same or different, but there seems little room for doubt that the red sandstones of Pokran are continuous with those of Lohawat and overlie the Vindhyan limestone.

14. Towards Jodhpur sandstones, which may or may not belong to the same series as those of Pokran, are largely exposed: frequently they are dark red, composed of well-rounded grains of quartz, but just as often are paler red and by no means infrequently white, the latter beds being usually as hard as the sandstones of Khátu. These latter frequently weather with small rounded bosses and occasionally

include thin bands of black ferruginous sandstone like that seen among the upper gondwana sandstones of Jessalmer.

15. These sandstones have previously been regarded as of Vindhyan age, but if they belong to the same series as the sandstones of Pokran, and if the Pokran boulder beds are the same as those of Báp, they must be much newer than Vindhyan, and might be of lower gondwana age. It is impossible to determine this point with certainty, but the balance of evidence appears to me very strongly against regarding the Jodhpur sandstones as of gondwana age; nor if this could be granted does the prevalence of red beds hold out any promise of the existence of workable coal.

16. It will be seen from the above statement of the essential facts that the prospect of finding workable coal is very small. Along the eastern boundary of the gondwana area upper gondwanas appear to rest unconformably on the boulder beds or even on the old crystalline rocks; there is no reason why the coal measures should not be present, hidden by upper gondwanas and recent sand, but any search for them would be purely speculative. Still, seeing the enormous value that would attach to any deposit of workable coal in this region it may be thought advisable to institute a search; in this case the best plan would be to sink a boring on the crest of the anticlinal between Jessalmer and Vinjorai, about 3 miles south of Devikot, where older beds than are seen to the north or south are exposed; it would be necessary to push this boring to as great a depth as possible or until the crystalline floor was struck.

17. I may point out that as yet only those localities which appeared most promising have been examined; that there is still a considerable area of rock country which has not been visited as the rocks are almost certainly of upper gondwana or even later age, and the discovery that the Pokran boulder beds underlie the sandstones of the Pokran scarp opens out a vista of possibilities which certainly deserve more thorough working out than I was able to give them at the tail end of the working season.

P. S.—Since writing the above I have had an opportunity of examining the rocks of the Salt-Range. Here there is a considerable series of rocks, known as the speckled sandstone group, at whose base there is a boulder bed precisely similar to, and probably the same age as that exposed near Bap. The rocks overlying it are very similar to the neozoic rocks of Jessalmer, except for the absence of the black ferruginous sandstone so common in the latter locality; in spite of this, the lithological relations of the Jessalmer beds with the Speckled sandstone of the Salt-Range are much stronger than with the gondwanas of the peninsular. In the speckled sandstone the only traces of coal known are a few thin papery layers of coaly matter, and it is very probable that there is a similar absence of coal in the Jessalmer rocks. In the absence of special search there can be no certainty on the subject, but, as before remarked, search would be speculative to a degree. I cannot say that there is no coal in Jessalmer, but that is the extreme limit my observations allow me to go to.

CAMP, SUTLEJ VALLEY;
The 31st May 1887.

A Facetted Pebble *from the* Boulder Bed, ("Speckled Sandstone") *of Mount Chel in the* Salt-Range *in the Punjab, by* Dr. H. Warth.

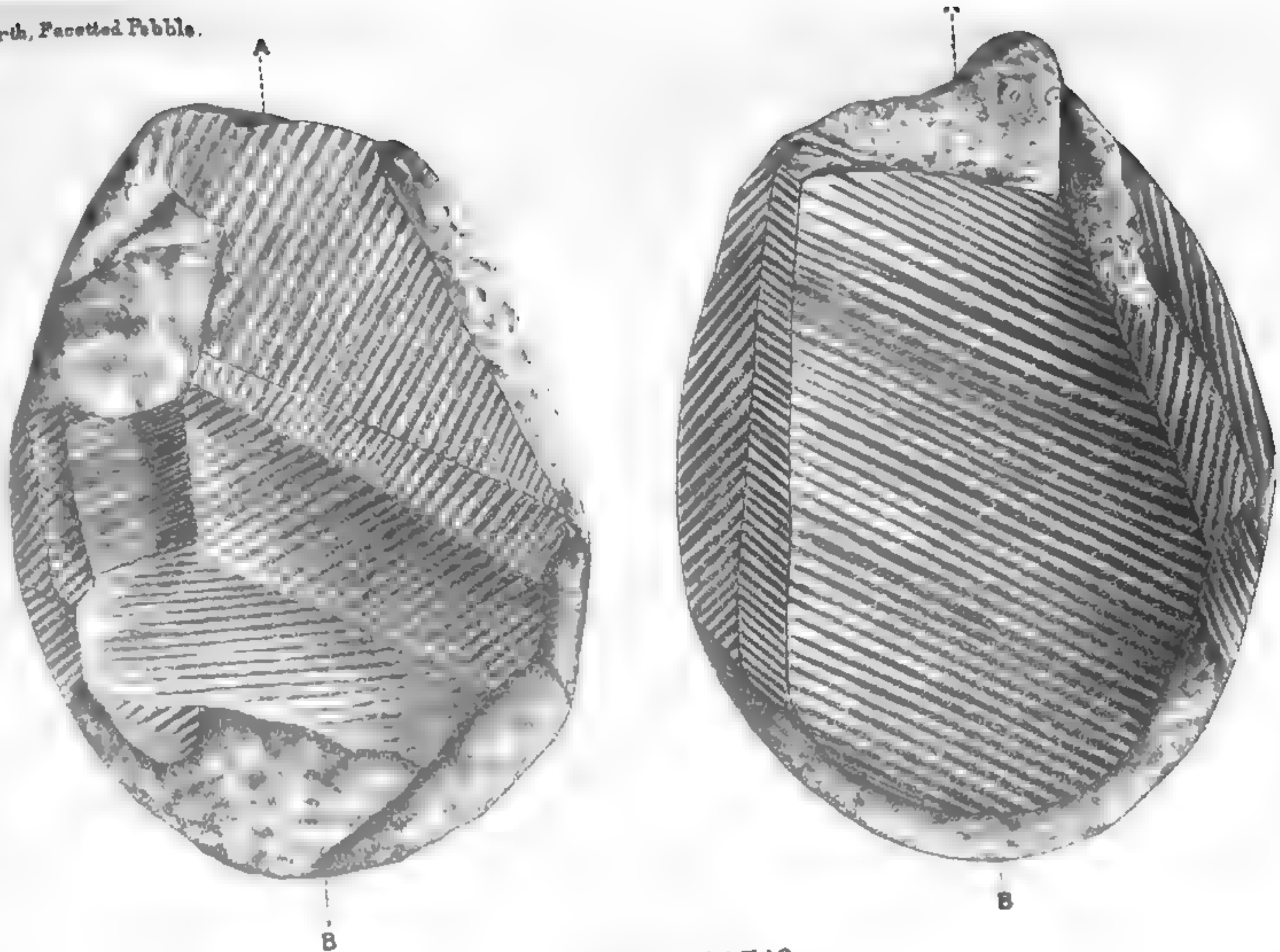
(With 2 plates.)

Amongst the facetted pebbles which I found in the Salt-Range is one with such a large number of polished surfaces and such distinct ice scratching that it deserves special description.

The annexed diagram[1] represents two opposite views of the pebble in natural size. The view on the right hand shews the largest of the polished surfaces, which is 10 centimeter's long and 5 centimeters broad. The number of faces is about 20 all counted, the very smallest being about 1 centimeter long and half a centimeter broad. The diagram shows the direction of the scratches on all the faces. The scratches are thicker on the right side of the faces, showing that the stone moved from the left to the right along the respective faces. The pebble must have been pushed by the ice along the floor of the glacier bed, and the whole movement may have lasted several hundred years; the stone during the time turning round so that the polished surfaces were necessarily produced. The angles between the faces vary considerably, and the stone moved also from side to side, so that it did not revolve regularly. But generally speaking it revolved in the mean round the axis A-B of the drawing. The direction in which the stone revolved was most probably such as would make it roll forward, and therefore on the diagram from left to right. Very likely only one total revolution took place during the whole passage of the stone under the glacier, and the faces took therefore each a very long period to form. About one-fifth of the surface is unpolished. The pebble weighs 680 grammes. The rock is red porphyry with a specific gravity equal to 2·566.

The pebble was obtained from the crystalline-boulder bed near the summit of Mount Chel. This mountain rises from the plateau of the eastern Salt-Range to a height of 3,700 feet. Magnesian sandstone forms the summit, but the crystalline-boulder bed which rests here directly on the magnesian sandstone comes close to the summit on the north-eastern slope. The actual boulder-bed, some feet thick, is accompanied by at least 25 feet thickness of greenish mud throughout which boulders are also scattered. The boulder-bed is exposed in section and also parallel with the surface. The surface exposure is more considerable. There is a large mass of boulders and pebbles scattered over several acres of surface on the actual site of the boulder-bed overlying the magnesian sandstone. Only the individual boulders and pebbles have been slightly shifted and re-arranged after the weathering away of the mud. It is on this area that I found about a dozen facetted pebbles, besides many other pebbles and boulders which had only one glaciated surface. I do not remember finding a facetted pebble on the outcrop of the vertical section of the boulder-bed, but this is only natural. When there is only one facetted pebble, amongst

[1] The sketch is very diagrammatic; the scratchings being indicated by very much broader lines than appear on the facets of the specimen; though the actual scratches are very clear and distinct. The second plate is a fairly accurate drawing. —*Ed.*



DIAGRAMMATIC.

PLATE I

Warth, Facetted Pebble

DIAGRAMMATIC

PLATE II

perhaps a thousand others, a large surface is required for search if the search is to be successful. I picked up the specimen under description with my own hand from the area of scattered pebbles. I consider it as a genuine specimen produced by glacier action, deposited by ice transport amongst the boulder-bed, and exposed on the breaking up and weathering of this bed *in situ*. If it was thought possible that a man would have shaped this hard porphyry and thrown it amongst the pebbles, how can we account in the same way for all the other specimens and the partly facetted ones here and in other parts of the Salt-Range. One and all must be the work of nature.

Examination of Nodular Stones *obtained by trawling* off Colombo, *by* E. J. JONES, A.R.S.M., *Geological Survey of India.*

The following acccunt[1] of these stones is reprinted from the Journal of the Asiatic Society, Bengal, as being of more direct interest in these Records:—

"The nodules were obtained during a trawling operation off Colombo in water of 575 fathoms, and are stated to have been found associated with sand and mud, which formed a hard calcareous crust at the bottom of the sea, and a small quantity of which was forwarded with the specimens.

"The stones are irregularly rounded, and vary in shape from almost spherical to roughly cylindrical with rounded ends. The specimens received varied in size from 1—4 inches in length and 1½—¾ inch in thickness. Externally, they are rough and mostly have one or two small excrescences of the size of a pin's head, and a few small pittings of about the same size; the colour is dirty light grey.

"On breaking them open, the fractured surface has much the appearance of an ordinary slate without the cleavage, and is of a much darker colour than the exterior. Running along the central line of a long cylindrical one which I broke open, there is a narrow vein of a brownish colour.

"A microscopic examination of a thin slice shewed merely a confused mass of aggregates resembling in their structure that of sphærulites, such as occur in the so-called sphærulitic lavas, with the remains of Foraminifera and Radiolaria disseminated throughout the mass. With ordinary light, little is to be seen except more or less radiating fibrous aggregates, but, as soon as the section is observed between crossed Nicol's prisms, the whole field is seen to be covered with little dark crosses

[1] Natural History Notes from H. M.'s Indian Marine Survey Steamer 'Investigator,' Commander Alfred Carpenter, R.N., Commanding. No. 5. On some Nodular Stones obtained by trawling off Colombo in 675 Fathoms of Water.—By E. J. Jones, A. R. S. M., Geological Survey of India. Journ. Asiatic Society of Bengal, LVI., Part II, No. 2, 1887.

with their limbs parallel to the planes of the prisms, and, on revolving the stage, the limbs of the crosses keep the same orientation whilst the section revolves.

"It is when thus observed that the aggregates are seen to be entirely distinct from one another, as each cross keeps to its one aggregate, and the crosses do not overlap; so that, by revolving the stage, the limit of each aggregate can be determined by tracing the path of the outer end of one of the limbs of the crosses.

"In the volcanic rocks in which this structure is known, it appears to be due to incipient crystallization in a glassy mass; and at first it might be supposed that these masses were of igneous origin. This idea, however, is untenable on account of the remains of Foraminifera (of several species, the most easily recognised of which are the globigerinæ) and Radiolaria which are sparsely scattered through the mass, and, in some cases, enclose a sphærulitic aggregate.

"An indeterminate greenish substance, which probably consists of glauconite, is also seen scattered through the mass.

"The only difference that can be detected between the central vein and the portion between it and the exterior is that the aggregates in the central vein are much larger and the colour brown instead of green, and that it is unacted on by hydrochloric acid, which dissolves out some calcic carbonate from the other portion.

"As mentioned by Mr. Daly in his letter forwarding the nodules, these are very heavy, having a sp. gr. of 3·77 at a temperature of 30° C. as against water of 4° C.

"A qualitative analysis shewed the nodules to consist in great part of baric sulphate together with small quantities of calcic and strontic sulphates, small quantities of calcic and magnesic phosphates, aluminic silicate, calcic carbonate, and traces of iron, sodium, and manganese.

"Not having the time to devote to a complete quantitative analysis, I made, in order to arrive at an approximate estimate of the proportion of baric sulphate present, a determination of the sulphuric acid. An average sample from two of the nodules powdered and dried at 100°C. gave 82·5°/₀ of baric sulphate, the whole SO_2Ho_2 being calculated as SO_2Bao''.

"This result is, however, of course too high, as a small quantity of the SO_2Ho_2 is combined with Ca. and Sr. in the form of calcic and strontic sulphates, though, from the results of the qualitative analysis, it is probably not much too high; and we may, I think, safely take 75°/₀ as the percentage of baric sulphate present.

"In order to see whether the material was derived from the mud in which the nodules occur, and which also contained Foraminifera, I made a qualitative analysis of the mud, and found it to consist mainly of aluminic silicate, with small quantities of calcic carbonate, some iron, and a trace of manganese; there was also a trace of an alkaline earth which was not removed by boiling with hydrochloric acid and subsequent washing, but this, on spectroscopic examination, shewed itself to be lime.

"In spite of the negative result of the analysis of the mud, I am inclined to think, from the presence of the Foraminifera both in the mud and enclosed in the nodules, that the latter have been formed at the bottom of the sea either at the spot where they were found or at no great distance therefrom, though it is difficult to imagine how the material was obtained, but it is possible that a careful analysis of a larger

quantity of the mud would reveal a trace of Barium, for sea-water contains a slight trace of this element.

"I cannot at present call to mind any instance of sphærulitic structure occurring without the aid of heat.

"'In volcanic lavas and in artificial glasses, it may be regarded as concretionary, or as resulting from incipient crystallization or devitrification around certain points or nuclei. The nuclei when they exist consist either of a granule or a minute crystal or crystallite, but most commonly no nucleus is discernible.[1]

"In this case, however, it would seem, that it must be due to slow segregative action; and, baric sulphate being very slightly soluble in water, the deposition would be very slow and may have been to some extent crystalline, at any rate sufficiently so to produce the same effect as incipient crystallization from a glassy mass.

[1] Rutley's Study of Rocks, p. 183.

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FROM 1ST OCTOBER TO 31ST DECEMBER 1887.

Concretions from beach abreast Saugor light-house.
PRESENTED BY MR. S. R. ELSON, CALCUTTA.

Three specimens of the meteoric irons of Youngdegin, Nejed, and Greenbrier County.
PRESENTED BY THE TRUSTEES, BRITISH MUSEUM, LONDON.

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Yours sincerely
H B Medlicott

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1888. [May.

Award *of the* Wollaston Gold Medal, Geological Society of London, 1888.

Annual General Meeting, February 17th, 1888. Professor J. W. Judd, F.R S., President, in the Chair.

In presenting the Wollaston Gold Medal to Mr. Henry Benedict Medlicott, M.A., F.R.S., late Director of the Geological Survey of India, the President addressed him as follows:—

"Mr. Medlicott,—The Council of this Society are not unmindful of the fact that many of our Fellows are engaged in the promotion of Geological Science in every part of a vast Empire; in awarding to you the highest honour which is at their disposal, they are following a precedent which was established more than fifty years ago, by the presentation of the Wollaston Medal to Cautley and Falconer. In that great Indian dominion where those famous geologists carried on their important researches, you commenced your labours as far back as the year 1854; and for more than a third of a century you have continued the almost incessant exertions which have led to very important additions to our knowledge, often obtained only at the price of severe hardships, and at the risk of serious dangers. During the last eleven years you have occupied the important and responsible position of Director of the Indian Survey; and it is to your administrative ability in that position that we owe many of the valuable results obtained by that Survey in recent years; more especially are we indebted to you, and to our Secretary, Dr. Blanford, for that useful Compendium of Indian Geology which has now become indispensable to all students of our science. We feel it to be singularly appropriate that we are able to make this award to you just at the time that you return to your native country for the rest you have so well earned."

"Mr. Medlicott replied:—Mr. President,—The award of the Wollaston medal by the Geological Society is the most gratifying distinction that a geologist can receive. It is only as a recognition of devotion to our science that I can venture to accept so great an honour. My work has been chiefly in combination with others, and it gives me much consolation to think that my colleagues of the Geological Survey of India will share in this reward, and will appreciate it."

The Dharwar System, *the* Chief Auriferous rock series *in* South India, *by* R. B. FOOTE, F.G.S., *Superintendent, Geological Survey of India.* (With Map.)

The promising development of the gold mining industry during the last five years having gone far to undo the mischievous effects of the wild gold speculation of previous years, greatly increased attention has been devoted to the auriferous rocks in Mysore, and the adjoining districts of the Madras and Bombay Presidencies and the Nizam's Dominions. A proof of this is furnished by the fact that a London publishing firm reproduced the map which I had given in illustration of my paper on "A traverse across some gold fields of Mysore," which appeared in the Records, Geological Survey of India (Vol. XV, part 4, 1882). Since the publication of that paper my official duties have taken me over large tracts occupied by the auriferous rocks both in the Ceded Districts (Bellary, Anantapur, &c.), and in Mysore; especially in the latter. Some of the information gathered about the auriferous rocks in the Ceded Districts was made public in the "Notes" published in 1886, "On the geology of parts of the Bellary and Anantapur Districts" (Records, Geological Survey of India, Vol. XIX, part 2). The additional facts collected as to the geology of the Mysore country were obtained during a visit to different parts of that State, made by desire of the Durbar with the object of my reporting on the auriferous tracts known to exist there, and about which separate reports had been previously drawn up by Messrs. Lavelle and Marsh. On completing this tour, which occupied the months of February, March, April and part of May of last year, I drew up a "Report on the Mysore Auriferous Tracts," which was published among the selections from the Records of the Mysore Government for 1887. My report was accompanied by a map showing the distribution of the auriferous rocks or "Dharwars" as then ascertained. This map, too, only claimed to be a sketch, and, as such, subject to modification when the country comes to be regularly surveyed. It was, however, a great advance on the first map published in 1882. In this report the subject of the auriferous rocks had to be dealt with from a purely economic point of view, and for non-geological readers, all technical expressions were, therefore, as far as possible banished from it, and no attempt made to illustrate the different features of purely geological interest. These are dealt with in the present paper. The map which accompanies it is on the same scale as that illustrating my "Traverse across Mysore" (Records, Geological Survey of India, Vol. XV, p. 4, 1882), and a comparison of the two will show that a very real advance has been made in the interval in ascertaining the extent and distribution of the Dharwar rocks. The map, however, is only put forward as an improved sketch to be superseded in its turn. Large additions to the extent of the Dharwar system will certainly have to be made on the map, as the geology of south and west Mysore, and the adjoining districts of South Canara, Coorg and Coimbatore is worked out. In the Ceded Districts, too, and most probably on the western side of the Dharwar Districts also, considerable areas of the Dharwar rocks have yet to be separated from the Gneissic system among which they were formerly reckoned.

The Dharwar rocks form a very well marked series (or system), consisting mainly of Schistose rocks (hornblendic, chloritic and argillitic) with associated,

more or less hæmatitic quartzites and numerous contemporaneous trap flows. In many parts of the areas occupied by these rocks occur quartz reefs and veins which are auriferous, indeed all the more important auriferous tracts as yet known in South India lie within such areas, and hence the rocks composing them have come to be called the auriferous series. The Kolar gold field unquestionably occurs in an outlying band of the Dharwar system, and so also the Honnabetta, Chicknayakanhalli, Kotemaradi, Honnamaradi, Halékal gudda, Malibennur, Chirashalli, Honnahatti auriferous tracts and the Honnali gold field (Kudri konda and Palvanhalli) in Mysore, and the Dambal gold field, in Dharwar District, which occur in one or other of the great bands. The majority, if not all the fifteen outlying auriferous localities, forming the west central group of my Mysore Report are also situated on detached areas or outliers of the Dharwars.

The name Dharwar why selected.

The name chosen for this great series of rocks, the "Dharwars," was selected on well recognized principles of geological nomenclature, from the district in which the separation into a distinct and separate system of the Schistose rocks was first recognized. Till then they had been grouped as part of the great South Indian Gneissic system. The necessity for such separation was pointed out by me in my memoir on the South Mahratta country (Memoirs, Geological Survey of India, Vol. XII, 1876), but I waited for further evidence of the stratigraphical relation of the Schistose series to the far more crystalline gneissics, and this was obtained during my traverse across Mysore in 1881, and by an examination of the rocks in the Sandur and Bellary hills in 1884-85. The Schistose rocks are very largely and clearly developed in Dharwar District, and the well known town of Dharwar stands on them. All things considered, no other local name seemed to have so many points in its favour and the name of Dharwar was therefore given to the schistose, or auriferous rock system.

Distribution of the Dharwar rocks.

A glance at the map will explain the distribution of the Dharwar rocks far more fully than would many pages of writing. The reader is therefore referred to the map, where it will be seen that the rocks occur in three great bands, continuous for great distances, between which, and to the north and east of which, are a considerable number of irregular patches and short bands, mostly of small size, which will be enumerated and in part described further on. The three great bands have been called respectively the Dharwar-Shimoga band (the most westerly of all at present known); the Dambal-Chiknayakkan-halli band, and the Pennér-Haggari band, which includes the great Hunugunda band extending from the Tungabhadra, north-west across the Raichur Doab up to the Kistna. Between the Dharwar-Shimoga and the Dambal-Chiknayakkan-halli bands lies (on the right bank of the Tungabhadra) a large patch, at the south end of which stands the large village of Kunchur (Coonchoor); only the extreme north end of this has been actually visited; it cannot therefore be described, though the bare nature of the hills made it easy enough to see that they did not consist of granites or gneisses. In the southern part of the space between the two great bands just named lies a considerable number of small patches, mostly narrow and band-like in shape, of which three may be named as important geologically. These are the Taggadur-

The great bands.

Minor bands and patches.

betta patch in latitude 13° 3′ N.—and longitude 76° 30′ E., the Bellibetta band, 16 miles to the south, and Honnabetta 24 miles south-east of Taggadurbetta. Twenty miles south of Bellibetta lies a group of three small auriferous patches which I will call the Sonnahalli group (to be described further on), and 22 miles east of this group is a solitary small patch, at Holgere, the most southerly auriferous tract which came under my notice in Mysore. This is a doubtful outlier of the Dharwars.

The Sandur and Copper mountain tract.

Between the Dambal—Chiknayakkan-halli band and the Pennér-Haggari band lies a rather large and very important tract of the Dharwars which here form the Sandur hills and the Bellary Copper mountain range, a group of hills in which the geological characteristics of this system may be studied to great advantage.

Bands north of the Pennér-Haggari band.

To the north of the Pennér-Haggari band in the country between the Tungabhadra and Kistna, are several short but important bands which will have to be described separately further on.

Lastly, must be noticed the band forming the Kolar gold-field, which lies far to the eastward of the southern part (as at present known) of the Dambal-Chiknayakkanhalli band. When the country intervening between it and the known part of the Pennér-Haggari band shall have been examined it is very probable that a connection will be traceable between the two bands.

Of the several bands and patches above enumerated, only those lying within the Bellary district proper, and a few miles of the Pennér-Haggari band in Anantapur district have been closely surveyed with the object of specially studying their structure and petrology. The Kolar, Honnali and Dambal gold-fields have also been studied carefully, but no good maps showing their topographical features fully were available, and in the two former so much of the surface is covered with cotton soil that very many points of difficulty could not be solved satisfactorily.

Origin of the schistose bands.

The occurrence of the Dharwar rocks over the face of the gneissic systems in such remarkable bands, or portions of bands, is a feature which at once arrests the attention and demands explanation. The explanation is that the Dharwars, as now seen, are the remains of a great sedimentary series which covered a very large area in what now forms the peninsula of India. The periods of sedimentary deposition were interrupted by periods of volcanic activity during which great flows of contemporaneous trap were poured out. Many such flows were formed in different parts of the Dharwar area, as in that which now forms the Sandur and Bellary hills, and further to the south-west the hills south of Chitaldrug and the Bababuden mountains.

The Dharwar rocks were at a very remote geological period exposed to vast lateral pressure, by which they were crumpled into great folds, which were then exposed to great denuding action, and largely eroded. This took place anterior to the deposition of the Kadapa and Kaladgi basins, which belong to the upper transition group. Both basins were deposited unconformably on the upturned, and greatly contorted and eroded beds of the Dharwar system. The great jaspery hæmatite beds of the Dharwar system furnished the bright coloured jasper pebbles which are so striking a feature in the basement and othel conglomerates of the Kadapa system.

The forces which caused the great crumpling of the Dharwar rocks had, of necessity, also much effect on the underlying gneissic rocks, and in various places

induced a parallelism of folds which gives locally great semblance of conformability. The section of the gneiss rocks exposed south of the southern end of the Sandur tract, shows the gneiss to have been affected by an anterior process of crushing from pressure, acting in a more or less east and west direction. This is noteworthy, as it shows that the peninsula was affected at no less than four periods by great, approximately east to west or west to east, thrusts; the two just noted, and two later ones, by which the Kadapa and Karnul rocks were respectively crumpled up into the great foldings they now show. Of these, the last would seem to have been the least energetic.

Only a brief description of the chief petrographical characters of the Dharwar rocks can now be given; the full description of the members of the system which occur within the limits of the Bellary and Anantapur country must be reserved till the final Memoir on that tract comes to be written, while those of the Dharwar rocks lying in other tracts will have to await the times when they may have been studied by other geological workers.

DESCRIPTION OF THE SEVERAL BANDS AND PATCHES OF THE DHARWAR SYSTEM.

I.—The Dharwar-Shimoga band.

Northern group of inliers.

This great band of the Schistose rocks appears at its northern extremity (in the Belgaum District) in several small inliers exposed by the denudation of the overlying Kaladgi rocks and Deccan Trap flows. These inliers present nothing very noteworthy, and may be dismissed with a mere enumeration. They are seven in number. The most northerly is the Gokak inlier covering some ten square miles around the town of Gokak. The second, or Kelvi inlier lies about a mile south of the first. Four miles to the S. W. of the Gokak inlier is the Padshapur inlier, a rudely cruciform valley, cut through the Kaladgi quartzites. In this the Dharwars are very badly seen, owing to the extensive alluvial deposits of the small Markandi river, a tributary of the Gatprabbha. The Dharwars are similarly very badly displayed in the small inlier exposed on the north side of the valley of the Belgaum nullah (some four miles N. E. of that town), which nullah forms the most southerly branch of the Markandi river. The other three inliers may be called the Wannur, Budnur and Seedapur inliers, from the principal villages within their limits, or close to them. The northern extremity of the great band south of the edge of the Deccan trap area is also very badly exposed; the surface of the schists, and indeed of the whole Sampgaum Taluq, being greatly masked by extensive sheets of cotton soil. The rocks chiefly seen are bands of hæmatitic quartzite, forming low bare ridges, which are in many cases traceable for many miles in extent; between them are beds of chloritic schist, generally of pale green colour. Argillites occur also, and are in parts considerably hæmatitic in their mineral character. Contemporaneous trap is also to be seen in the valley of the Belowaddi nullah.

North end of the main bands.

Gold washings in Sampgaum Taluq.

Near to Byl Hongal and Belowaddi, the sands of several streams are reputed auriferous, and used formerly to be washed for gold; so also the nullah at Hatti Katti near Belowaddi. The accounts given of the amount of gold found in this quarter are rather conflicting, the earlier records representing it as much more important than at present. All the enquiries made by myself on the spot, and for me by the local authorities, showed the gold industry to be practically extinct. Extremely few traces of quartz-reefs are to be seen on cursory inspection, but the country is closely covered by cotton soil and by great accumulation of hæmatite derived from the great beds of hæmatitic jaspery quartzite which occur so numerously. I followed the Dharwar rocks from the valley of the Malprabbha at Sangoli southward to Tegur, and thence south-eastward to Dharwar town. The schists, argillites and hæmatitic bands continue all the way, and as far as the eye can reach, on either side of the road. The schistose rocks are, in their appearance, so utterly unlike the gneisses and granites flanking the great bands, that it is generally very easy to recognize the character of hills and ridges when seen in strong sun light from distances of many miles even, more especially when the ridges are continuous. The extreme bareness of vegetation of most of the ridges also greatly facilitates the recognition of geological features from long distances. The northern part of the Dharwar-Shimoga band forms, roughly speaking, the western boundary of the great black plain, the regur flat of Dharwar District. From Dharwar, I followed the band down to Hubli, and from high ground there could see it extending miles away to the S.S.E. Newbold describes a great schistose band crossed by him in travelling from Sirci (N. Canara) to Gadag (Gudduck); this can only be the extension of the Dharwar-Shimoga band. At Harihar it crosses the Tungabhadra, and from here I have either followed it personally or traced it by the eye in unmistakable beds over by far the greater part of the area which I have represented it as occupying. Some parts of it I have coloured in as of Dharwar age, from the conviction that the beds I have crossed and identified as forming the northern ends of great ridges, will assuredly be found to extend as far as those ridges are seen to stretch without any change in their physical characters and appearance. The excellent delineation of the topographical characters of such ridges in the 1-inch maps of the Topographical Survey of Mysore, assures me that my inference of such extensions of the Dharwar rocks is quite justifiable, and I feel assured that my inferences will be confirmed. This is specially the case with the tract lying between the Tunga and the Bhadra rivers. Of the southerly extension and strike of the Dharwar rocks in the great ridges south of Kumsi there can be no doubt. As seen from the Honnahatti hill, near Lakki-valli, the same characters of the continuous ridges is seen to extend far to the southward, and the same continuous character of orographic feature strikes the eye forcibly when looking south-westward from Kalhattigiri peak on the Bababuden mountain. Unless the topographical features of the mountains around Kalasi peak are utterly misleading, and from my experience of the remarkable agreement of topographical feature and geological formation over very great part of Mysore, I cannot believe that to be the case, the Dharwars extend far southward of what I have indicated, and form the

Near Dharwar.

South of the Tungabhadra.

Near Lakki-valli.

great mass of Ballalraiyandrug, and extend still further south, down into the low country of South Canara.

Gneissic inliers in the central part of the band.

The representation I have given of the Dharwar rocks around the Honnali, Saulunga, Shimoga and Tarikere gneissic inliers is, I feel convinced, a near approximation to the truth. The eastern part of the north boundary, and the southern boundary of the Honnali gneiss inlier, I lay down from actual survey. The eastern boundary is formed by bold hills whose western base must coincide very nearly with my lines. Of the Shimoga inlier, I have followed more than half the boundary lines, and the same was the case with the Tarikere inlier. To the east of the Shimoga inlier, I think it possible that an inlier, or some small inliers, may occur between Channagiri and Tarikere, and so also with regard to the tract between Belur and Banavar further to the south: but this is merely a surmise.

To the west and east of Hassan, I have shown two narrow bands of Dharwar rocks extending southward, neither of which I had the opportunity of following to its extremity. Of the extension of the western band I could not form any opinion; that of the eastern band will, I expect, be found running down nearly to the Çauvery.

From the very rapid character of my journeying over the central part of the Dharwar-Shimoga schist band (the Honnali gold-field excepted[1]) the information I gathered was necessarily fragmentary, but nevertheless it throws much light on the petrographical structure of the band, and is therefore worthy of record, and I will give my observations in geographical order proceeding from north to south.

At Harihar the Dharwars are greatly masked by the alluvium of the Tungabhadra, and by the almost ubiquitous cotton soil. Large banks of coarse shingle occur both north and south of the town. Underlying the shingle, schist crops up at intervals along the road to Mallé-Bennur. South of the Haridra (the little river which has been dammed back to form the great Sulekerra tank), a considerable show of contemporaneous trap appears through the cotton soil spreads.

At Mallé-Bennur.

At Mallé-Bennur a remarkable bed of coarsely brecciated quartzite makes a great show, forming a conspicuous ridge which has been utilized to form great part of the bund of a small, but deep tank. South of the tank the breccia bed runs up into and forms the backbone of a much more important ridge. It becomes increasingly hæmatitic and less and less brecciated as followed southward. The dip of this bed is eastward.

Underlying this brecciated hæmatitic band is a considerable thickness of chloritic schists, in the upper part of which are many laminæ, and small nests of crystalline limestone. A very good show of gold was found on washing the sand of a small stream which flows into the tank from the western slope of the ridge just mentioned. The gold is probably derived from some of the many small blue quartz veins cutting the chlorite schist. No large reefs were visible. Underlying the schists is a bed of trap apparently of contemporaneous origin. To the west of the trap flow, but not seen in contact, is a quartzite so much altered by crushing and weathering that it has in parts assumed quite a gneissoid appearance. This is followed downwards

[1] The Honnali gold-field so called, which formed the western extremity of my traverse across Mysore in 1881,—lies along the south side of the Honnali gneiss inlier. The two principal mines that have been opened in it are those of Kudri Konda and Palvanhalli.

(stratigraphically) by a thick band of dark schist, chiefly argillitic, which in its turn is underlaid by a great thickness of pale green and grey schists of variable character, but chiefly chlorito-micaceous. Small beds of quartzite are intercalated here and there, and veins of white and pale bluish quartz are numerous but very irregular in size and shape. These beds form the main mass of the Hanuman-betta hill group.

The schist series here makes a great curve, the western part trending west and crossing the Tungabhadra some 15 miles to the westward, while the south-eastern part trends south, and may equally be followed by the eye for many miles, forming very considerable hills and ridges.

The Honnali Gneiss inlier.

On getting down to the low country at the south end of the ghat leading to Honnali, an inlier of granite gneiss is reached which occupies the greater part of the valley of the Tungabadra, between the town and the gold-field known as the Honnali gold-field. The western extension of the beds which cross the Tungabhadra north of Honnali town forms a band of hills of considerable importance which can be seen to stretch away north-westward for a great distance.

The south-west side of the inlier is bounded by a great fault by which the gneissic rocks have been brought up and exposed over a large area by the erosion of the Dharwar beds which formerly covered them. The fault extends along the whole south-western side of the inlier and crosses the Tungabhadra. I did not follow the fault across the river. The eastern boundary of the inlier, like the northern one, is a true erosion boundary.

Honnali gold-field.

The belt of country on the south-west side of the inlier which constitutes the Honnali gold-field was carefully examined by me in 1881, and in part re-examined last year. The northern part of the belt is occupied by a great thickness of chloritic schists, underlaid to the south by a great mass of quartzites and conglomerates with some argillites. These, from their superior hardness, have been much less denuded than the chloritic beds and form, especially in the north-west part of the belt, hilly ridges of considerable height. The Honnali gold-field is divided by the Nyamti nullah into divisions of pretty equal length and breadth, which may be conveniently called the Kudrikonda and Palvanhalli divisions, after the two important gold mines which have been already opened on them, the former to the west, the latter to the east, of the Nyamti nullah.

In the Kudrikonda, or western division, chloritic schists only show in the plains, but in the eastern division, east of Palvanhalli mine, numerous intercalated quartzites, quartzite sandstones, and gritty beds appear, and rise into good-sized hills as they are followed eastward. The great contortion these beds have undergone has caused considerable local metamorphism, and the true detrital character of the gritty beds is in many places not apparent; where, however, they are coarse in texture, and approach in character to pebbly beds, their true origin can be recognized at once. This is the case also with regard to the great beds of conglomerate and flaggy quartzite in the lofty Kalwa-Rangan-betta ridge which forms the south side of the Kudrikonda division of the gold-field.

The Saulonga inlier.

To the south of the Kalwa-Rangan-betta ridge, lies another inlier of gneiss of considerably smaller area than the Honnali inlier just referred to. It appears to owe its origin to an important fault

running north-west along its southern boundary, and somewhat parallel with the great fault which forms the south-west side of the Honnali inlier. Owing to the thickness of the soil and extensive jungle, the gneissic rocks are but little seen at the eastern end of this inlier where crossed at Saulonga by the high road from Honnali to Kumsi. Near the centre of the inlier however, some small rocky hills of granite gneiss show up sufficiently to be recognized from the top of Kalwa-Rangan-betta. Any one not having seen these might easily cross the inlier at Saulonga without becoming aware of its existence.

The Dharwar rocks are very little exposed in the Kumsi hills which lie south of this Saulonga gneiss inlier, owing to the dense forest covering them, but the shape of the hills clearly indicates the continuance westward of the beds which form the hilly tract along the northern side of the Shimoga gneiss inlier, the largest of the whole group of four forming such a striking geological feature in the north-western corner of the Mysore territory. At the north-western end of the inlier, some of the beds, which in the Kumsi hills have an east-to-west strike, trend south-westward and form the great ridges forming the Shankar-gudda and Kormur-gudda hills, which may be seen to extend for many miles southward. Another part of these beds trends north-west in the direction of Sorab, but they have not been followed beyond a point a little to the north-east of Anantapur.

The Shimoga inlier.

South of the Saulonga inlier lies a very much larger one, in the centre of which stands the town of Shimoga, the south-western boundary of which is also formed by one or more faults running north-west to south-east, which are very apparent even on cursory examination, but the extremities of the fault line are obscure, owing to the extensive jungle prevailing to the south of Kumsi and north-west of Tarikere. To the south of the inlier occurs the promising auriferous locality known as Honnahatti, where some noteworthy old workings were found by me in chloritic schists traversed by well-marked quartz reefs. The chloritic schists strike north-west to south-east with a steep dip to the north-east. The Honnahatti workings stand on the narrow strip of the Dharwar rocks, which separates the Shimoga inlier from the Tarikere inlier, the last and most southerly of the group of four. Washings in the small stream draining the south side of Honnahatti gave very fine shows of gold.[1]

[1] NOTE.—A special feature demanding notice in the western half of the Shimoga inlier, and still more striking over the gneissic tract of the Dharwars near Anantapur is the development of lateritic rock which covers the surface almost ubiquitously and to considerable depth, rendering it extremely difficult to find any outcrop of the underlying older rock. I have not attempted to show the laterite on my map separately from the gneiss on which it mainly lies, as my brief visit to this north-west corner of Mysore did not afford me time to determine the relationship between the rocks. I did not see enough of the laterite to feel satisfied as to its being of true detrital origin or merely a product of weathering, as is much of the laterite on the southern parts of the Deccan trap described in my South Mahratta Report (Memoirs, Geological Survey of India, Vol. XII, 1876). The laterite which I am (so far as my observation goes up to the present) inclined to regard as formed by weather action, constitutes a nearly uniform cover to the whole country, whether it be flat or hilly, with a generally pale, reddish, more or less clayey surface, which affords but little nourishment to vegetation. The grasses, especially seem to thrive very badly and are very coarse in quality, a chief reason probably why cattle and sheep succeed so badly in the Malanad, as the forest clad, western portion of Mysore is locally designated by the natives.

The existence of a great fault along the south-western boundary of the Tarikere gneiss inlier has not been proved, but I have no doubt it will be shown to exist whenever the country may be geologically surveyed. The rocks are very little exposed either in the area of the inlier or in the ridges of Dharwar age which surround it. Extensive jungle and great spreads of soil effectually hide the rocks in most places east of the Tarikere inlier; a change takes place in the nature of the country, the great jungles are met with no longer, and the slopes of the hills being exposed to unchecked denudation, show an abundance of outcrops of all kinds.

The Tarikere gneiss inlier.

Along the south side of valley running eastward of Tarikere are numerous outcrops of quartzite with schists, and near the eastern end of the valley appear great outcrops of an extraordinary conglomerate of extreme coarseness. The pebbles, often approaching in size to small boulders, consist of granite or compact granite gneiss cemented together in a foliated chloritic matrix. The beds culminate in a considerable hill, called the Kaldrug in the Indian Atlas (sheet 57), which presents a most rugged appearance. The beds east of the conglomerate are largely quartzites which form a high ridge with a great cliffy scarp on the eastern face of "Coancancul" peak (Atlas sheet No. 60). East of these, again, comes a great thickness of pale chloritic schists. These schists extend north of the Tarikere valley, and form the hills north-west of Ajimpur, and extending up to and beyond Chiranhalli, where washings in the small streams cutting across them yielded very satisfactory indications of gold. The conglomerate beds appear also to be represented on the north side of the Tarikere valley, for a long line of excessively rugged outcrops shows to the west of the schistose band in a strictly corresponding position. The Chiranhalli pale chlorites are largely mixed with pale talcose schists, both of which rocks contain very numerous crystals, mostly small, of cubical iron pyrites, and further numerous octahedra of magnetic iron. These latter are locally distributed.

Kaldrug Conglomerates.

To return to the west end of the Tarikere valley, a large development of chloritic schists occurs extending southward for a considerable distance. South of these, and underlying (?) them, come great thickness of trap flows, which form great part of the great Santaveri spur, joining the lofty Dodda Bala Sidderu mountain (5,136 feet high) with the yet higher mass of the Bababuden mountains, which here attain an elevation of 6,155′ in the Kalhattigiri peak. The trapflows are disposed in a very flat anticlinal curve, and to the west are seen to be overlaid by a great thickness of dark schists (? argillites) with hæmatitic bands and quartzites overlying them again. These schistose beds are splendidly exposed in the great scarp which runs all along the eastern side of the Bababuden mountains from north of Kalhattigiri to south-west of Mallaingiri, the most southerly peak of the mass (6,317′) and the highest point in Mysore State.

Santaveri Section.

To the south of Chik Magalur, and again to the south-west of the Sigegudda mountain, north-west of Hassan, the basement bed of the Dharwar system is formed by pebbly quartzites dipping north- and north-east respectively. The latter beds are seen to extend southward along the western side of the narrowing band of Dharwars described above (page 45) as running north-westward of Hassan. Quartzites overlaid by

Basement beds near Chik Magalur and Sigegudda.

schists form the narrow band of Dharwars which runs south from near Harnhalli close to Narsapur, and constitutes the southern extremity as far as yet known of the Dharwar-Shimoga band.

II.—*The Dambal—Chiknayakkanhalli Band.*

As in the case of the Dharwar-Shimoga band, the northern extremity of this tract of Dharwar rocks is very badly seen, owing to the vast waste spreads of cotton soil which cover the great plain forming the eastern half of the Dharwar District. The only exposures of any importance of the Dharwar rocks in this part, are beds of schist and hæmatite in the scarps of the Nargund and Chick Nargund hills below the cappings of quartzite of the Kaladgi series (Kadapas) which form the summit plateaus on both hills and rest on the Dharwar beds in the most marked unconformity. The Dharwar beds are upturned at high angles and dip 50°—70° east by north in the Nargund hill, the quartzite capping of which, a finely scarped plateau, is approximately horizontal. At Chick Nargund the quartzite capping has a dip northward, while the schist beds on which it rests have a strong dip to east by north.

Sections at Nargund and Chick Nargund.

Nearly equidistant from the two Nargund hills to the westward, a patch of contemporaneous trap rises above the cotton soil surface and forms a blocky ridge about 3 miles long by half to three-quarters of a mile wide. The rock is a diorite (?) of dark greenish colour.

Asmatti Trap-flow.

I did not follow the band up from Nargund, but marched south-west to Naulgund where there is a hill capped by a singular inclined plateau of a rock which may be a quartzite, very highly metamorphosed, but may also represent a run of the brecciated quartz which occurs so commonly in the granite gneiss area, adjoining and throughout the granitoid areas of the Ceded Districts. The plateau inclines to the north at an angle of about 45° which is a lower dip by far than observed elsewhere in any quartz run of unquestioned character,—still on the petrographic evidence of the rock itself it appears rather to be such a quartz run, greatly depressed by some local faulting, or other, than an altered quartzite of the Dharwar system. No exposure of the Dharwars was observed by me in the bed of the Bennihalla, the large stream which after draining this region, falls into the Malprabbha near Badami town. Whether any outcrops of the rocks occur between the Bennihalla and the northern extremity of the Dambal hills near Gadag (Gudduck) is uncertain; but there is every reason to suppose that a strong band of them exists under the cotton-soil spread, for a great thickness of chloritic schists rises out of the plain already a little to the north of the high road leading from Gadag (Gudduck) to Hubli. South of the road two great bands of hæmatite schist stand out conspicuously among the other softer schistose rocks, and may be followed continuously for ten or twelve miles south-eastward.

Naulgund hill.

Chloritic schists near Gadag.

Further south, another apparently underlying hæmatite band with associated chloritic, hornblendic, micaceous schists and crystalline limestones forms an anticlinal arch and is overlaid to the westward by another hæmatitic band, and this again by two

The Dambal gold-field.

others with associated argillites of reddish-buff or mottled whitish colours. These are greatly affected by cleavage, which completely obscures the bedding in many places, and renders their stratigraphical relations to the rocks next succeeding to the westward very problematic. This next series consists of chloritic and hornblendic beds intimately associated with a massive dioritic (?) rock, probably a contemporaneous trap, which covers a belt of country some 4 or 5 miles wide, and abuts to the westward against the granite gneiss which here forms a broad band extending westwards till it is overlaid by the eastern edge of the Dharwar-Shimoga band near Luxmaishwar, as described by Newbold.[1] The two most westerly beds of the hæmatite series form the mass of the Kappatgode, the centre and highest point of the plexus of hills which occupies the southern part of the gold-field.[2]

Surtur trap flow.

The auriferous nature of the rocks of the Dambal gold-field has long been known, and the surface of several of the quartz reefs been broken up by native miners at some former period. Gold washing is still followed by a few "Jalagars," professional gold washers, particularly in the larger streams rising on the area occupied by the contemporaneous trap above mentioned. The two largest nullahs, known respectively as the Surtur and Dhoni nullahs, from the principal villages near which they flow, are the richest in gold sand. The quantity of gold obtained is small, too small indeed to tempt many to engage in washing for it. Quartz reefs occur in all parts of the gold-field, but those found in the western part among the chloritic and argillaceous schists adjoining the trap area, are the best defined, and have received most attention from the old miners. They are doubtless the principal source of the gold obtained there. The only reef from which I obtained free gold was one of this set. It lies on the eastern slope of a ridge about 8 miles due west of Dambal, and has a north by west, south by east course, with a hade of from 40° to 50° east, and is about half a mile long.

The auriferous reefs.

Hattikatti reef.

A few small excavations hardly worthy of the name of pits had been sunk along the eastern side of the reef at some time prior to my visit, but I could not obtain any satisfactory information as to whom they had been sunk by. As already mentioned, I obtained no gold from any of the other reefs, and the indications of gold from washings in the streams draining the sites of the other groups of reefs to the eastward of the Kappatgode hill were far from encouraging.

The quartz of the Hattikatti reef from which I got the specimen of free gold, and of the majority of the reefs throughout was of the ordinary kind, white or milky in colour, but very largely iron-stained in parts. The group of reefs occurring south of the village of Dhoni on the east side of the Kappatgode[3] differs from all the others in consisting of distinctly bluish, or deep grey, diaphanous quartz, with a few enclosed scales of white or pale mica.

The Dhoni groups of reefs.

[1] In his paper on the Geology of the South Mahratta Country, and elsewhere.

[2] A more detailed account of the rocks forming the Dambal will be found in Part 4, Vol. VII of the Records, Geological Survey of India, 1874, in my paper on the Auriferous Rocks of the Dambal Hills, Dharwar District.

[3] Shown in the map accompanying my paper referred to above.

The reefs, excepting that of Hattikatti, and two others a little distance to the S. W., showed no sulphides of any kind, and; those three yielded only a very few cubical crystals of iron pyrites. The argillites and chloritic schists, however, show great quantities of cubical crystals of that mineral converted into limonite by pseudomorphism.

The different members of the Dharwar system occurring in the Dambal area are seen to extend far south in the band of hills stretching away down to the valley of the Tungabhadra, which they cross and re-appear on the south side in the Haddagalli taluq of the Bellary District. The intermediate part of the band has not yet been examined, but being very bare of vegetation it is very easy to see the disposition of the outer beds on either side from a moderate distance. To the east of the band, the beds there, as further north near Gadag, are faulted against the granite gneiss, the downthrow being on the west side of the fault. The fault crosses the Tungabhadra and runs on for some 4 miles, when it is crossed or joined by another fault, running nearly east-north-east to west-south-west, and is no longer traceable to the southward.

The Tungabhadra gorge section.

To the west of Dambal town the band of Dharwar rocks is fully 13 miles wide, but it narrows greatly as it approaches the Tungabhadra, being a little less than 5 miles across in the gorge of the river. The section here seen shows, when followed from east to west, the following series:—

10 Hornblendic schists.
9 Hornblendic trappoid.
8 Contemporaneous trap.
7 Trappoid.
6 Flaggy hæmatitic quartzite.
5 Boulder conglomerate.
4 Contemporaneous trap.
3 Schists and argillites.
2 Hæmatitic schists.
1 Hornblendic Trappoid.

Of these the conglomerate is the most noteworthy because of its extreme coarseness, many of the boulders included being more than $1\frac{1}{2}$ foot in diameter. The conglomerate is very little altered, apparently, and boulders which have weathered out are perfectly smooth and water-worn. None were seen showing any striations on groovings.

Continuance of the band into Mysore.

The hornblendic schists seen at the eastern end of the gorge section extend southward, and appear to form the backbone of the high ridge forming the bold Bettada Mallapan Gudda. The extension of the beds forming this ridge may be clearly traced by the eye for a long distance south-east. The ridge sinks down as it approaches the valley of the Chinna Haggari, south-east of which detached hills of schistose rock indicate the continuance of the Dharwar band up to and across the Mysore frontier. Another ridge of hills rises here and connects the Dharwars of Harpanhalli taluq with those around Jagulur.

Honnamaradi gold-field.

A few miles south of Jagulur occurs another auriferous tract that yielded highly promising quantities of gold on washing the sands of two streams rising on the west and east sides respectively of the little hill lying north of Honnamaradi. The hill consists of

drab or yellowish gritty schist passing into argillite in parts, on the south-western side of which several medium sized reefs of quartz appear running nearly north and south. Immediately east of the Honnamaradi (golden hill), the gneissic rocks are seen with an apparently faulted boundary in between. On the bank of a small nullah which flows south, a couple of hundred yards to the east of the hills are the remains of some large dumps where the old jalagars had evidently washed the sands for a considerable time. A washing of "dirt" from the bed of the nullah gave a handsome show of gold, of good grain and excellent colour; while a washing from the little rivulet flowing from the western side yielded a rich show of very coarse gold of the highest quality.

No gold was seen *in situ*, but there is every reason to believe it came from the reefs above referred to, as the streams in which the washings were made, especially the western one, have such very short courses that they could not have brought their gold-supply from any great distance. West of the schist beds forming the Honnamaradi hill and the tract westward of it, appears an underlying bed of jaspideous quartzite which has been tremendously brecciated by some obscure cause. The rock weathers of a very dirty dark colour, nearly black in many places, and is often very obscure in character and hard to determine. The breccia character becomes obvious only when the enclosed jaspideous pieces are paler than the matrix.

The Goeshwar hill trap flow.

West of, and underlying the brecciated quartzite is a great development of contemporaneous black trap (diorite ?) which extends southward a long way and forms great part of the mass of the fine Goeshwar hill, the loftiest hill in the band northward of Chitaldrug.

Kotemaradi gold-field.

Proceeding southward still, we come to the Kotemaradi auriferous tract, which consists of a great bed of chloritic schists overlaid by quartzites, and these again by a thick series of other schists, the lower beds being argillites. Traces of a contemporaneous trap show along the western basement of the Dharwars.

Quartz reefs are rare or else covered up by the extensive talus. The only one of any size seen was a good-looking one of bluish quartz running through chloritic schist at foot of the western slope of the southernmost of the three big hills which rise northward of the little Kotemaradi hill. The reef is just north of the stream draining the western slopes and close to some old workings of small extent.

Quartzites a possible source of gold.

The quartzites on the Kotemaradi are of no great thickness, and are locally much altered, nearly converted in many parts into true quartz, and generally permeated by large numbers of small quartz veins. It will be curious to ascertain, as doubtless there will ere long be opportunities of doing, whether this altered quartzite contains any gold. It is certain that the small stream draining the western and northern slope of the Kotemaradi carries down a notable quantity of large gold of excellent colour, and that no reefs of any size or importance show through the extensive talus covering the slopes.

Chital drug granite hill.

To the south of Kotemaradi, the Dharwars form a small bay opening to the west, at the southern side of which stands the old town

of Chitaldrug, with its grand old granite hill capped and surrounded by a noble fort or Drug, formerly one of the centres of the Bidars, one of the bravest and most independent of the Hindu tribes in the Deccan.

Jogamaradi trap flow.

Belligudda copper mines.

To the south of Chitaldrug the basement bed of the Dharwars is a great contemporaneous trap of great thickness and extent which forms the summit of the Jogamaradi, one of the highest mountains in this part of Mysore. Overlying this great trap formation is a great thickness of schists, some of which form the Belligudda (hill) noteworthy as having contained some considerable pockets of copper ore, which were exhausted by miners of whom no record appears to exist. The ore mined was, as far as can be judged from the refuse heaps, an earthy malachite, or carbonate of copper. No signs of a lode can be seen running through the clay-schist forming the Belligudda. The axis of the hill is a hard bed of jaspideous hæmatite quartzite which stands nearly vertical.

Halekalgudda side band.

To the south of the Jogamaradi mountain, south of Chitaldrug, the width of the great band is nearly doubled by the junction with it of a parallel band, which commencing somewhere to the south of Harpanhalli [1] forms the Halekalgudda and some other hills east of Maya Konda, and then sweeps into the main band. A little to the east of the junction, the Dharwar beds attain their greatest elevation in this part in a peak to which the Trigonometrical surveyors assign a height of 3,863′ above sea-level.

The geological structure of this side band, which may conveniently be called the Halekalgudda band, shows no special features so far as it was examined, unless it be a rather greater development than usual of gritty, locally conglomeratic quartzites. With these are associated siliceous, micaceous and chloritic schists. These are underlaid by a great flow of dioritic trap which in its turn is underlaid by a considerable thickness of schists. Some fine quartz reefs cross the footpath crossing the hill south-westward from Halekalgudda village, but none were seen near it, though a good show of gold was obtained by washing near the north end of the hills. Where the highroad from Chitaldrug to Holal Kere crosses the southern part of the Halekalgudda band the country is very flat and much obscured by thick red soil, but the connection of this band with the main one is made clear by the existence of a low ridge formed by an outcrop of a purely ferruginous bed of hæmatitic quartzite which rises rapidly, both to the north-west and south-east, and soon becomes an important object in the landscape.

The fine views to the south obtained from the tops of Belligudda and Jogamaradi show the Dharwar rocks extending far to the southward in great force towards the great gorge by which the Haggari river (locally known as the Varada) cuts through the hills of the Dambal-Chiknayakanhalli band, while from the south from the highest point east of Chiknayakanhalli town the beds are seen to range continuously northward to the same point. Though not traversed as yet by the geological surveyors, there is ample evidence as to the existence of the Dharwar rocks between the known tracts near Chitaldrug and Chiknayakanalli.

[1] The northern extremity of this side band has not yet been visited, so its exact position is not known. It extends about 50 miles in length.

At Chiknayakanhalli we come again upon an auriferous tract which is frequently spoken of as the Chiknayakanhalli gold-field. On Honnebagi hill, a couple of miles south-east of the town, old workings of no great size occur just within the boundary of the Dharwar area. The reefs occurring here are not promising in superficial appearance, being white and hungry-looking; but the quantity of gold obtained by washing in the small streams flowing down the hill is not by any means contemptible, and deeper prospecting might give still more favourable indications.

The Chiknayakanhalli gold field.

The basement bed is here a quartzite which is overlaid by a thick series of schists, hornblendic, chloritic and micaceous, occupying the space up to the foot of the hills, where they are overlaid by argillites and a great thickness of hæmatitic schists, locally very rich in iron. The weathering of the highly hæmatitic schists gives rise to the formation of subaerial breccias which assume a lateritoid appearance from the action of percolating rain water. The denudation of these rich, red argillites and hæmatites gives rise to the formation, further to the south, of an extensive talus of deep red soil.

Dodrampur hill synclinal.

The stratigraphical position of the main ridge east of Chiknayakanhalli appears to be an elevated synclinal, but the eastern side shows a succession of formations discordant from that on the west, and there may very probably be a fault running parallel with, but a little east of the axis of the synclinal.

About half-way down the eastern flank are extensive and important formations of sub-crystalline limestone, mostly grey in colour, and with very numerous siliceous partings in the form of quartzite which here and there attain to the magnitude of distinct beds. These limestones must be several hundred feet thick. East of the little fortified temple of Dodrampur they are underlaid by a great chloritic schist formation. The limestones cover a large area stretching away south-east from the main ridge and a small show of them is to be seen on the west side of the main ridge, just opposite the mouth of the deep gorge east of Ballenhalli.

Dodrampur limestones.

To the south-west of Chiknayakanhalli lies a branch of the band which runs north-west some 14 or 15 miles from its point of divergence from the main band. Where crossed by the high road from Shimoga to Bangalore, it is seen to have a great flow of trap as its base, on which rest chloritic and other schists to a considerable thickness. To the south of the point of divergence just referred to, the whole band trends strongly eastward, and keeps on the left bank of the upper course of the Shimsha river. I was unable to follow it up east of the Shimsha, but I feel convinced that the Dharwars stretch away south-west by Kunigal, and then south, past Huliyurdroog and further south, narrowing greatly the while, across the Madras railway. The hills stretching away south of the Yadiyur-Kunigal road present the dark colour and smooth appearance so characteristic of the Dharwar rocks elsewhere, while the country round Huliyurdroog is well known to be auriferous, and the look of it from the railway near Mudgeri station on the Mysore State Railway assures me that it is so.

Kibbanhalli branch band.

Kunigal-Huliyurdroog extension of the main band.

become numerous and convert the reefs into true granite veins; rocks which are not as a rule rich in the precious metal.

Karigutta felspar porphyry.

The most southerly point to which the Shettihalli band has been examined is the Karigutta hill overlooking Seringapatam. The most striking feature here is a very fine large dyke of beautiful, reddish-brown felspathic porphyry, which might furnish an inexhaustible supply of a superb decorative stone fit for vases, panels, bases for busts, and tazzas.

The extension of the Shettihalli band southward of the Cauvery has not yet been followed up by me. But there can be no doubt that it does extend much further. I am not prepared, however, to support fully the idea which I fathered in the map accompanying my paper on the traverse across Mysore, that the Shettihalli band extended far to the south-west and joined the band of auriferous rocks forming the Wynaad gold-field, I have therefore indicated no such connection in the new map.

Notes on the Igneous rocks *of the districts of* Raipur and Balaghat, Central Provinces, *by* PRAMATHA NATH BOSE, B. Sc., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With a plate.)

The igneous rocks treated of in these notes occur in the jungle-clad border country forming the water-shed between the districts of Raipur and Balaghat, and situated north of Dongargarh, and west of Lohara, Gandai, and Khairagarh. They are, as a rule, unbedded; and they alternate with ridges of Chilpi shales and sandstones, which are probably of Transition age. Their general parallelism to the strike of the Chilpis is notable.[1]

Area; mode of occurrence.

Felsites.—These are almost exclusively confined to the eastern portion of the area, only a small patch having been encountered in the western portion, east of Bijagarh in the district of Balaghat. The ground occupied by the Felsites in the eastern area may be sub-divided into two portions—one lying to the north of Thakurtola, and the other to the south of that place. In both of these areas, they run north-south parallel to the strike of the sedimentary Chilpi strata; and in both, the eastern and western boundaries are approximately straight.

South of Doomureea (a village 3 miles west of Lohara), as well as near Koylaree (west of Silheti), the felsites were seen to be in lateral contact with highly altered vitrified quartzites. A mile north of Doomureea, on a felsite-hill locally known as Dalhea, I came across huge blocks of a hard, laminated, quartzitic-looking rock, which looked as if they had been carried up entangled in the felsitic mass. Small patches of shales and quartzites with the Chilpi strike, and belonging apparently to the Chilpi series frequently occur in the midst of the felsites, especially in the

[1] For a general geological map of a portion of the area, *vide* Rec. G. S. I., Vol. XVIII, p. 169.

ote.

country west of Doomureea. They look like remnants of beds which have been forced through by the felsites. One such patch was well seen just west of Magarkund. It is surrounded on all sides by the felsitic rocks.

The absence of bedding, the straightness in direction of the felsitic outcrops, the alteration visible in the adjacent rocks at places, and the presence of included Chilpi fragments, as well as of patches of Chilpi rocks in the form of islets, suggest the intrusive origin of the felsites.[1]

Age.

East and south of Thakurtola, as well as west of Khairagarh, the felsites are overlaid with a certain degree of unconformity by sandstones and conglomerates, which form the base of the Chhattisgarh Plain Series, and to which the name of "Chandarpur sandstone" has been applied. Chandarpurs lying in hollows scooped out in the felsitic rocks is rather a common occurrence. We may hence infer, that the felsites are older than the Chandarpurs. The fact, that at places, as at Lumna (north of Thakurtola) and elsewhere, the basal conglomerates of the Chandarpur group contain rolled fragments of the felsites corroborates the inference. There are a few circumstances, however, which lead me to think, that the felsites cannot be much older than the Chandarpurs. It is even possible, that minor intrusions continued while the latter were being deposited. The vitrified quartzites west of Koylaree, and south of Doomureea, referred to above, have not been traced into indubitable Chilpis; and the occurrence of Chandarpurs in their neighbourhood raises the not unreasonable suspicion, that they may belong to that group. West and north-west of Thakurtola there are tuffs associated (to all appearance, interbedded) with the lower Chandarpurs; and these tuffs may have been formed of *ejecta* from felsitic dykes in the Chandarpur period. The felsites would thus appear to have been intruded through the Chilpis prior to, and possibly also, in part contemporaneously with, the deposition of the Chandarpurs.

Felsites intruded close to shore and parallel to coast line.

The small thickness and breccio-conglomeratic character of the Chandarpurs plainly declare them to be a shore deposit, and the Saletekri range (formed of Chilpi rocks) probably indicates the coast-line of the lake or inland sea in which they were deposited. The felsites would thus appear to have intruded as dykes close to shore, and parallel to the strike of the Chilpis, as well as to the ancient shore-line.

Petrography.

The typical form is a purplish rock much rent by fissures, and weathering to a brownish tint. The fracture is roughly conchoidal. Longish crystals of white felspar, and roundish ones of vitreous-looking quartz are macroscopically seen to be disseminated in it. The former are larger than the latter, some measuring as much as quarter of an inch in length. In the matrix, as well as in the crystals of felspar, a greenish decomposition product is often observed, sometimes to such an extent as to change the colour of the latter entirely to green.

[1] Intrusive felsites have been noted by Dr. King in the Kadapah formation (Chey-air beds), which is possibly of the same age as the Chilpis (Mem. VIII pp. 191, &c.). The remarkable parallelism of the felsites to the Chilpi outcrops, and the fact that they are seldom clearly seen to cross the strike, give them an appearance of being contemporaneous flows. But the presence of included fragments and of patches of Chilpi rocks is unfavourable to such a supposition.

Under the microscope, the groundmass is seen to be micro-felsitic. It is made up largely of minute slightly greenish, granules. Numbers of them are in some slides seen collected in interrupted, irregular, and more or less wavy lines. In a slice prepared from a specimen of a felsite which, though obtained from the southern portion of the district of Raipur, a little way to the south of the area under description, unquestionably belongs to the same series as the felsites we are treating of, microlites looking very like those in question are seen to be aggregated along the outer boundaries of the quartz and felspar crystals, appearing, as if, in flowing past these, they had met with some obstruction, and in consequence stuck together (H, Fig 1, Plate). These bundles of microlites are somewhat elongated and strongly dichroic in polarised light. There can be hardly any doubt, that they are microlites of hornblende. And it is not improbable, that a portion of the minute greenish granules of the felsite under description also belong to that mineral.

The larger quartz crystals have invariably a more or less rounded shape, and the edges are not very clearly defined. Fluid inclusions are abundant. Protrusions of the groundmass (G. Fig. 2) in the form of bays, and also along narrow cracks are common. Isolated patches of the groundmass are found in some, though rarely; and a few contain cubical crystals of oxide of iron. The smaller crystals of quartz, unlike the larger ones just noticed, usually exhibit more perfect crystal surfaces.

The crystals of felspar are invariably impellucid, being full of granular matter. They are usually rounded off at the corners, some appearing nearly elliptical in section. Their outline, like that of quartz crystals, is, in some cases, very ill-defined. As in the case of quartz, inclusions and intrusions of the groundmass are not uncommon. The characteristic twinning of orthoclase is exhibited by some in polarised light. No plagioclase has been observed. Cleavage lines are sometimes well seen as in fig. 1.

Some of the appearances noted above in connection with the crystals of felspar and quartz would seem to suggest, that they have not crystallised *in situ*. The seemingly isolated patches of the groundmass found enclosed in some crystals may, in reality, be connected by cracks with the groundmass outside, the connection being cut off in section. The frequent indistinctness of the crystal boundaries may be accounted for by partial fusion along the edges.

The greenish alteration product, patches of which are, in some cases, macroscopically seen in the matrix, as well as in the crystals of felspar is noticed, under the microscope, to be slightly dichroic with polarised light. Even where the product in question has invaded the entire felspar crystal, so as to appear macroscopically a pseudomorph of the latter, it is found, under the microscope, to be quite patchy, the unaltered portions of the felspar exhibiting various bright colours under crossed nicols.

At Khairbana and generally along the eastern margin of the felsitic area, there occurs a non-porphyritic purplish felsite associated with tuffs at places. The rock is much fissured and has a very uneven fracture. It is eminently liable to alteration, being sometimes almost wholly converted into quartz-rocks, as near Gubra, and sometimes into pseudobreccias. No bedding, however, is noticeable anywhere; and here and there unaltered portions of the matrix are met with.

A thin slice of a specimen from near Khairbana has a blotched appearance,

small brownish spots and patches being interspersed in a light purple matrix. Under the microscope, a few small bits of rather pellucid felspar are noticed, which appear to be fragments of much shivered larger crystals. They are partially rounded off at the corners; and the brownish substance noticed above invades them to some extent.

It is doubtful if the rock is a genuine felsite. It is probably a tuff, at least in part, belonging to the felsite series.

A dark coloured felsite occurs at Murghusri, Mohanpura, &c. On a fresh fracture, the felspar crystals are barely recognisable with the naked eye. But, on the weathered surface, which is light brown, somewhat as in the porphyritic variety, they are conspicuous by their white colour. Owing to the similarity of appearance at the weathered surface, the variety under consideration could not be distinguished from the porphyritic variety noticed above, without devoting to the rocks more time than I could command. The former possibly belongs to an intrusion different from that of the latter. Certain it is, that the black felsite differs from the purplish porphyritic form, not in colour only, but also mineralogically, in the extreme rarity of free quartz in it, and chemically, in containing proportionately less silica. The percentage of silica, as ascertained by analysis in the survey laboratory, in the porphyritic quartz-felsite is 73·47, but in the felsite under notice only 68·57. This last proportion just exceeds the maximum limit of silica (66 per cent.) present in intermediate igneous rocks.

Under the microscope, the groundmass is seen to be microfelsitic, as in the porphyritic form. The larger crystals of orthoclase are full of minute granules (the result probably of kaolinisation), and have their corners more or less rounded off.

Area, mode of occurrence.

Basaltic rocks.—These occur in the Chilpi area north of Dongargarh and, like the felsites, run parallel to the strike of the Chilpis. They cover the entire ground about Ghoteea, Bunnara, &c., forming an ill-defined range of scraggy hills. On the north side they abut laterally against a high ridge of sandstones sloping gently with the dip north-westward. The junction on this side is fairly straight; throughout it, however, the sandstones were nowhere clearly observed to have undergone any special alteration. The eastern junction, east of Ghoteea, is similar to the northern. Along the southern junction, however, the sedimentary Chilpis were found to be distinctly and highly altered. North of Koolharghat, and just south of Lingungarh, as also south of Ghoteea, there were met with along the junction, dark, bedded, igneous-looking rocks, resting on Chilpi sandstones with perfect conformity. They contain more or less rounded grains of quartz in abundance, and at places, look like gritstones or even conglomerates, with a trappean base. South-east of Ghukooree, there occur at the junction peculiar looking schistose rocks. Both these classes of rocks appeared to me to be the result of contact metamorphism.

West and north-west of Luchna, the basaltic rocks occupy a very large area extending to north of Bukkurkutta, where they are covered by laterite. Patches of shales, and more rarely of sandstones, belonging evidently to the Chilpi series, and similar to those occurring among the felsites, were encountered in the basaltic area

An alternation of basaltic rocks, which appeared like minor dykes, and quasi-schists was met with on the Kaman pass (one of the passes between the districts of Raipur and Balaghat).

North of Mahuadhar and just south-west of Nemao Tola, there is a ridge of the basaltic rocks, in which blocks and boulders of quartzites of all shapes and sizes, some measuring no less than 20 feet in length, were encountered.

At places, as just west of Sitapala, the Chilpi shales in contact with the igneous rocks were found to be altered into hard thick claystones. Elsewhere, as west of Kurela (Karol on map), a peculiar-looking schistose grit somewhat like the rock mentioned above as occurring south-east of Ghukooree, was met with as contact rock. Frequently, however, the shales and sandstones in contact were found to have undergone no special alteration.

Relative age.

The facts noted above with regard to the mode of occurrence of the basaltic rocks appear to indicate that they are of intrusive origin. The fact that they follow the strike of the Chilpis very closely may suggest, as in the case of the felsites, that they are contemporaneous flows. But, as in the case of the felsites, the presence of patches of Chilpi shales and sandstones in the midst of the basalts cannot on this view be satisfactorily accounted for. The mode of occurrence of the basaltic rocks in the vicinity of Ghoteea and Bunnara, however, gives rise to the suspicion, that they belong to a flow contemporaneous with the Chilpis. For the latter are remarkably altered south of Ghoteea, at the southern junction. But no such alteration was noticeable at the northern junction, *i.e.*, the junction with the higher beds of the series. This junction, however, was much covered by *debris* from the sandstone hills, and was. altogether very obscure. I would not, therefore, lay much stress on this negative fact, *viz.*, the absence of alteration; and the basaltic rocks of the neighbourhood of Ghoteea, like their fellows occurring further north, have in all probability, an intrusive origin ; are, in fact, intrusive sheets. There is, however, considerable uncertainty about their age. There is a minor intrusion of them in the felsitic area at Magarkund, and another a little way south, at a place called Bagdoor. An intrusion of the rock was also met with north of Magarkund in the country west of Lohara about Katangi-Mohanpura. The manner in which these intrusions occur left the impression in my mind that they are more recent than the felsites and felsitic tuffs by which they are surrounded. I have got no data which would fix their age with greater precision. Unlike the felsites, they are nowhere superposed by the Chandarpur sandstones, or, indeed, by any other sedimentary rock, except by laterite on the Saletekri plateau.

Lithologically, the rocks under treatment differ in a very marked manner from the felsites, but resemble the Deccan and Malwa trap basalts, though not closely; and for all that was seen in the field, they might be of the same age as the latter.

Percentage of silica.

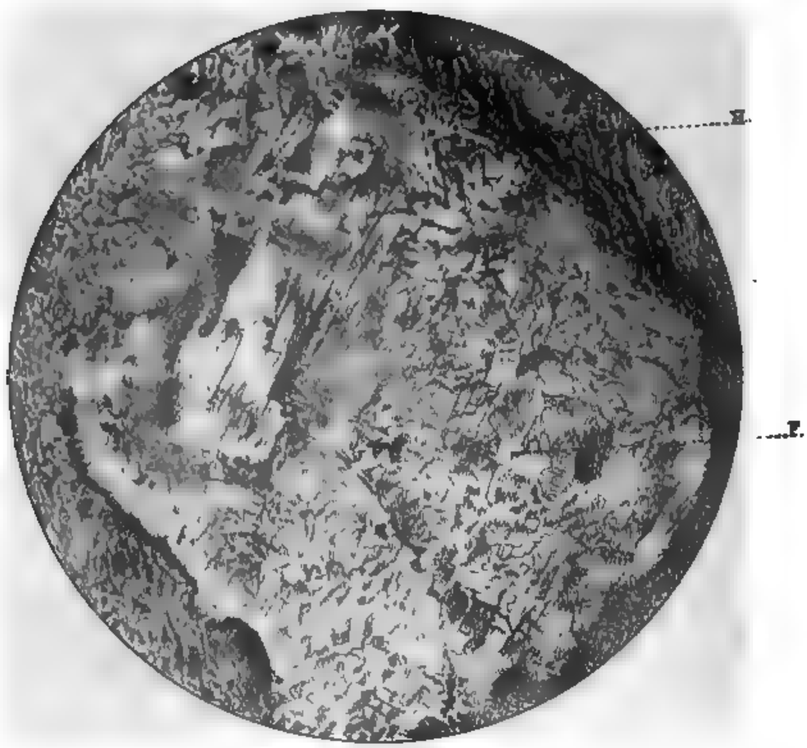
By analysis of a specimen, in the laboratory of the Geological Survey, it has been ascertained, that the rock contains 49·57 per cent. of silica.

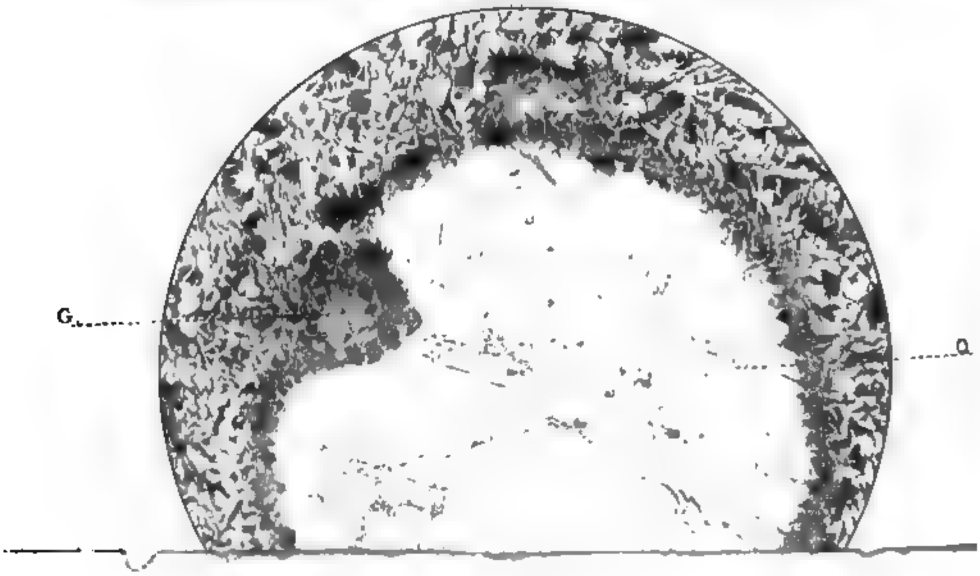
Petrography.

The basaltic rocks are hard, black, and compact. Macroscopically, black rod-like, minute crystals are visible in some. Under the microscope, these crystals are seen to be of a greenesh tint, slightly

ose.

Fig: 1.





but distinctly dichroic. They are as a rule irregular shaped; but a few eight-sided sections have been noticed. The mineral is, in all likelihood, augite. The groundmass is crypto- to micro-crystalline. Minute, rod-like, whitish crystallites, probably of felspar, are present, as also greenish microlites. Large felspar is rare; when present it is ill developed, and barely distinguishable as plagioclastic. Magnetite occurs, but not in such abundance as in the Deccan and Malwa trap basalts.

In mineral and chemical composition, the rock presents close analogy with basalts.

Tuffs, volcanic agglomerates.—The association of tuffs with the Lower Chandarpurs west of Thakurtola has been already alluded to.[1] The most characteristic variety is a gritstone-like rock, very hard and massive-bedded, and weathering in huge, roughly spheroidal masses. Their matrix varies in colour from nearly black to very light pink, presenting various intermediate tints. The black forms are the most volcanic-looking, and the light the most sedimentary-looking. In fact, the last named varieties pass almost insensibly into ordinary whitish gritstones, as at Manpur and Lumna. Macroscopically, the gritstone is seen to contain large quantities of felspar and quartz in about equal proportion. The felspar varies in colour from white to flesh-coloured, and is, in the average, of about the same size as the orthoclase of the felsites. The quartz, however, is much larger than that of the last-named rocks.

Under the microscope, the matrix, which appears nearly homogeneous to the unassisted eye, is seen to be full of little bits of felspar and quartz. There is some interstitial matter, which is somewhat like the groundmass of the felsites. The felspar is found to be of the same species as in the felsites; some of the crystals bear evidence of abrasion at the edges. The quartz crystals have a most irregular outline, and like the felspar, have undergone some amount of attrition.

That the gritstone-like tuffs are water-laid, there can be hardly any doubt. They are, in all likelihood, formed partly of volcanic ejecta, and partly of sedimentary material.

The possibility of the non-porphyritic purplish felsites in the neighbourhood of Khairbana being, at least partly tuffs has already been adverted to. The fine-grained tuffs vary considerably in colour from purplish to black. Some are smooth and homogeneous with conchoidal fracture; others rough, with rather coarse and uneven fracture. The tuffs not unoften pass almost imperceptibly into well recognisable, clearly bedded sedimentary strata, as north-west of Bagdoor, north of the road leading from Gandai to Thakurtola.

EXPLANATION OF PLATE.

Figs. 1 and 2. Porphyritic Quartz-Felsite, south of Khuji, Raipur district.
,, F. felspar.
,, Q. quartz.
,, H. bundles of horneblende microlites.
,, G. Groundmass.

[1] *Vide* page 56.

Report on the Sangar Marg *and* Mehowgala Coal-fields, Kashmir, *by* TOM D. LATOUCHE, B.A., *Geological Survey of India.* (With one plate.)

Two areas in which coal-bearing rocks (which, for the purposes of this report, may be called "coal measures," though this term must not be taken to imply any connection with the true coal measures of Europe) are found, were examined by me,—the one occurring on the western and northern flanks of Sangar Marg hill, and the other in the valley of the Neari Tawi river, a tributary of the Bari Tawi, about 8 miles to the west of Kotla, surrounding the village of Mehowgala. These may be called the Sangar Marg and Mehowgala coal-fields respectively, and I shall describe them separately. The coal measures are probably continuous between these two areas, though separated at the surface by a broad band of newer rocks; but in most places are at too great a depth to be reached by mining. I spent only a few days in the examination of the Mehowgala field; but as the rocks met with are practically the same as those at Sangar Marg, and as they are much less disturbed by folding, I was able to form an opinion on their extent and condition more rapidly than in the case of the latter field.

I.—THE SANGAR MARG FIELD.

Geology.—The following is a vertical section of the rocks exposed in the field, such as would be found in a boring or well, sunk vertically through the strata where horizontal. It should be remembered that where the strata are inclined, as they almost invariably are in this field, the thickness of each bed passed through by a vertical boring would be greater than that here shown, in proportion to the angle of dip; also, the thickness of the different beds may not be exactly the same over the whole area, though that of the whole group appears to be very constant. For instance, I found the thickness of the band of carbonaceous shale immediately overlying the coal seam to vary from 3 to 10 feet within a short distance, and the thickness of the seam itself is also variable. The amount of overlying Murree Sandstone passed through would, of course, depend on the position of the boring if commenced in that rock. Its total thickness is unknown, but must be several thousand feet. That of the Great Limestone, too, at the base of the series is unknown, its base being nowhere exposed:—

Formation.		Description.	Thickness, feet.
Murree Group . .		Grey and reddish-grey sandstones, with beds of shale, weathering purplish-red . . .	Undetermined.
Subathu Group (coal measures) . .		Nummulitic limestone, upper band, hard blue limestone, with large nummulites . .	4
	Upper shales.	Olive shales, with occasional thin nodular calcareous bands, sometimes containing small nummulites passing down into .	200
	Upper shales.	Finely laminated olive shales . . .	
		Nummulitic limestone, lower band . . .	

Formation.		Description.	Thickness, feet.
Subathu Group (coal measures)—*contd.*		Earthy limestone, crowded with small nummulites	20
	Middle Shales.	Shales, sandy near top, passing down into carbonaceous shales at base. . .	125
		Thin band hard sandstone, with pyrites . .	3
		Carbonaceous shales	3 to 10
		Coal .	2 to 5
	Lower Shales.	Finely laminated olive shales, carbonaceous near top	70
		Indurated pisolitic clay	5
		Brecciated conglomerate with iron ore . .	Variable.
Supra Kuling Series.		Great limestone	Unknown.

It will be seen that the greater part of the coal measures consists of shales, with a few subordinate beds of harder rock, and that the coal seam occurs in the lower part of the formation, the shales on either side of it being carbonaceous. There is in this field only this one seam of coal, which is always found at or about the same horizon in the shales; the lower band of nummulitic limestone is a very useful guide to the position of the seam in any outcrop of the coal measures; as, being a hard rock, it weathers out more or less conspicuously from the surrounding shales, and the coal will always be found, if at all, at a certain distance beneath it.

In order to describe the distribution of these rocks in the coal-field, it will be convenient to take the lowest formation exposed, *viz.*, the *great limestone* (so named by Mr. Medlicott), as the higher rocks are everywhere conformable to the folds into which it has been thrown, except where the boundary between them is a faulted one.

This rock forms the main mass of Sangar Marg hill, where it is thrown into the form of a broad anticlinal curve or arch, with its axis running approximately east and west. This anticlinal is flanked on either side by two synclinal curves or troughs, occupying the valleys near the head of which the villages of Bugoola and Sujanpur are respectively situated. I shall accordingly speak of them as the Bugoola and Sujanpur synclinals. On either side of these again, the *great limestone* is bent up in narrow anticlinal folds, forming, on the south, the precipitous ridge to the north of Berh, and on the north a similar ridge along the northern side of the Sujanpur valley. In its easterly continuation along the line of the Puddar valley, this fold is faulted parallel to its axis.

The axes of all these curves are elevated towards the east, so that the anticlinals disappear gradually in a westerly direction. At the same time the synclinals between them broaden out. Thus the narrow ridge of *great limestone*, north of Berh, disappears near the village of Kroli on the path from Berh to Kotla; the *great limestone* forming the main or Sangar Marg anticlinal, disappears about $1\frac{1}{2}$ miles west of the tank at Chakur; and that forming the ridge north of Sujanpur, near the lower end of the Sujanpur valley. Similarly, the depressions caused by the synclinals grow shallower, and tend to disappear in an easterly direction.

To the south of this system of folds, the rocks are much disturbed and faulted, and even inverted in places, so that the *Murree sandstones* are sometimes in contact with the *great limestone*, or appear to dip beneath it, as may be seen along the path leading from Berh near the village of Kroli; while the coal measures are either faulted out of sight, or so broken up as to be valueless. To the north, *Murree sandstones* apparently extend to the foot of the Punjab range.

Owing to the combined effect of the folds into which the rocks have been thrown, and the denudation to which they have been subjected, the coal measures appear at the surface as a continuous narrow band, running in an irregular direction between the *great limestone* and *Murree sandstones*. The area occupied by the *Murree sandstones* may be readily distinguished from that of the *great limestone* by the purplish-red colour of the soil formed by the weathering of the former, and the more rugged character of the hills formed by the latter.

Distribution of the Coal measures.—It is difficult to convey an accurate idea of the distribution of the coal measures without a large scale map; but I have prepared a section taken across the western portion of the field in a direction transverse to the strike of the rocks, which will be of some assistance in distinguishing the various folds I have described above. The section is attached to this report.

a. The Bugoola synclinal.

Entering the Kotla valley by the path from Berh, coal is first met with on the top of the low pass or *col* near the village of Kroli (or Krool, which is somewhat to the east of its position as marked on the map).

The seam where first seen is a good deal disturbed, but seems to be from 4 to 5 feet thick; a short distance to the west, however, it is reduced to 2 feet 9 inches. The dip is apparently towards the *great limestone*, but within a few feet to the south, the dip of the overlying rocks is about 67° to S. W., or away from the *great limestone*. To the south-east of this point, the coal measures occupy a small valley at the foot of the *great limestone* ridge north of Berh, and are cut off to the south by a fault.

On the descent from the pass above mentioned to the Kotla valley, the coal measures follow the path for about $\frac{1}{4}$ mile to a patch of terraced fields; here they bend sharply to the east round the western end of the narrow ridge of *great limestone*, and enter the Bugoola valley. Along the southern side of the valley, they are deeply eroded, and generally concealed by cultivation and debris from the limestone ridges, but coal is exposed in more than one place; the dip is high to north. Near the upper end of the valley, at the place called Kala Mitti by the natives, the band of coal measures bends again sharply to the west along the northern slope of the valley. At the bend, denudation of the shales containing the seam has exposed it in such a manner as to make it appear that there is more coal here than else-

where; hence the distinctive name given to this spot. That there is, however, a considerable thickness of coal here, I found by a cut made across the beds where they were not denuded, and by a pit sunk some 300 yards to the west, along the southern outcrop. In the former place, the seam was 3 feet 6 inches thick, and in the pit 7 feet 6 inches. This pit afforded a striking instance of the manner in which the seam may be concealed by surface soil. At the surface, only a few inches of coal were visible, and that only where the grass had been worn away by a foot-path, and yet not 10 feet below there was this thick seam of coal.

Along the northern side of the valley, the coal meaures, dipping steeply to the south, are again eroded as far as the village of Kori, where a ridge of *Murree sandstone*, jutting out from the southern flank of Sangar Marg hill, has escaped denudation and protected them. Coal is again exposed on the *col* at the top of this ridge, between Kori and Ransu on the left bank of the Tawi, and again to the west at the lower end of the ravine near Ransu, just above the fields belonging to the village. On the *col*, the seam is 4 or 5 feet thick, and in the ravine about 3 feet.

The centre of the valley is everywhere occupied by rocks higher in the series than the coal seam; that is, by the upper beds of the coal measures towards the head of the valley, and by *Murree sandstones* lower down; so that the coal might be reached either by vertical mines on the floor of the valley, or by horizontal adits driven at points low down on its sides. In the middle of the valley, however, these upper rocks are nearly vertical, and it is impossible to say at what depth the coal seam would be reached. This could only be determined by boring. I do not think that for a mile at least down the valley from Kala Mitti, this depth would be found too great for mining on English methods; though in the lower portion of the valley a considerable water discharge would have to be contended with. Working from the outcrop should in no case be permitted in such highly inclined seams, as such openings would greatly facilitate the passage of water into the seam.

On the banks of the Tawi stream, near Ransu, the coal measures are entirely concealed by cultivation; and, where they cross the river, by its deposits of gravel and boulders. To the west of the stream they appear again in the ravine along which runs the path to Chakar, and coal is exposed on the path itself in more than one place as far as the *col* where the path from Brehal to Chakar is met. On the *col*, the coal seam is 2 feet 6 inches thick, dipping to S. 15° W. at about 20.° Down the ravine towards Brehal, the thickness of the seam increases, but at the same time the dip becomes much higher, until at Brehal it is nearly vertical. Here the seam is from 4 to 5 feet thick, but the shales in which it occurs are much contorted on a small scale, and the coal is crushed to powder. To the south, however, the dip of the rocks overlying the coal decreases, though still very high, about 70° in a southerly direction; and the coal would probably be found improved in condition if reached by a mine; but even at a short distance from the outcrop, it would be at a great depth owing to the high dip. Further to the west of Brehal, the seam again grows thinner. It is last seen in a small stream about ½ mile to the west of the Brehal outcrops, and is only 2 feet 2 inches thick, but with a lower dip, 37° to S. 20° W.

To the south of Brehal the dip of the rocks overlying the coal, as may be seen from the accompanying section, is very high, as far as the Tawi, and in the level ground near the river, the coal seam must be at a great depth beneath the surface;

but it might be worth while to make a boring to the south of the river near the village of Kahiar, which is almost in a line with the sharp anticlinal ridge of *great limestone* at Kroli, and where the coal measures may be brought up within a reasonable distance of the surface.

b. The Sujanpur synclinal.

Ascending the hill side to the north of Brehal over *great limestone* and breccias, coal is next found about ½ mile to the west of the tank at Chakar, at the base of a scarp formed of coal measure rocks overlaid by *Murree sandstones*. When first seen, the seam is only 1 foot thick, and appears to die out entirely to the west where the coal measures bend down towards Brehal over the top of the main anticlinal (*vide* section).

To the east, the seam increases gradually in thickness as far as a point about 100 yards north of the tank, where it is from 4 to 5 feet thick. Here the coal measures bend to the north along the gully leading to the head of the Sujanpur valley, the thickness of the seam again decreasing until it is only 1 foot 4 inches at a point about 800 yards north of the tank. Beyond this, it disappears as a seam, and is represented at intervals by highly carbonaceous shales with lenticular beds or pockets of coal as at the top of the *col* above Sujanpur, and again about half way down the valley on the north side. Towards the lower end of the valley no coal is seen, but the coal measures are much concealed by talus from the steep ridge of limestone to the north.

At the village of Saroda-bar, on the top of Sangar Marg hill, is a small outlying patch of coal measure rocks which occupies the head of the Sujanpur synclinal, and has hitherto escaped denudation. The outlier is of no great extent, and its position at the top of the hill probably renders it worthless for mining purposes, just as at Kala Mitti, the amount of coal exposed by the denudation of the seam is apparently large, but this appearance is rather deceptive.

c. The Ikni and Paddar outcrop.

At the lower end of the Sujanpur valley, the band of coal measures makes another sharp bend round the western end of the narrow ridge of *great limestone* to the north, and runs due east in the direction of Ikni. It is probable that a fault exists along this line which has dropped the lower part of the coal measures out of sight in places; but even where fully exposed, until the ravine close to Ikni is reached, no coal is seen in them. The dip all along this line is very high, about 60° to the north, and the *Murree sandstones* overlying the coal measures rise into lofty hills directly from the outcrop, so that mines could not be sunk to the north of it so as to reach the coal except at a very great depth; though adits might be driven horizontally in a few places to the south of the outcrop so as to undercut the seam. The thickness of the seam at Ikni is variable, but reaches as much as 8 feet in places.

To the east of Ikni, the coal measures are continued along the same line down the Paddar valley, but are occasionally cut out by the fault, which gradually increases in throw, the *great limestone* to the south of it forming a lofty scarp along the southern side of the valley. Coal is seen about half way between Ikni and Paddar, very shaly and nearly vertical; and again at Paddar village[1] itself, where a few pockets

[1] This village is not in the position marked on the map, but is about 3 miles due E. of Lena station.

occur in vertical shales. Below Paddar, the coal measures are eroded and concealed by talus, but may be traced as far as the Rad stream which joins the Chenab at Arnas. Crossing the Rad stream, they enter the hilly country to the north of it, dipping steeply to the north between *great limestone* on the south and *Muree sandstone* on the north, but appear again on the same line at the junction of the Aus and Chenab, and may be traced for some distance up the valley of the latter river to the east. The coal measures, as a whole, seem to be much thinner here, but the different limestones and shales are all represented, and near the village of Kantan, about 1½ miles east of Arnas, I found a small pocket of coal in them. Beyond Kantan, they again enter the hilly ground to the north of the Chenab, and I did not trace them further; but in this direction the coal appears to be confined to small pockets in the shales.

Condition of the Coal.

In all places where the coal is exposed at the surface, it is found to be in a very friable and flaky condition, crumbling easily between the fingers. This is partly due to weathering, and partly to the crushing the rock has undergone during the folding of the rocks. In order to find out whether the coal improves in the interior of the seam, I had a pit sunk near the tank at Chakar so as to reach the coal where it had been unaffected by weathering: the pit was 120 feet from the outcrop in one direction, and 190 feet in another, and coal was reached at about 30 feet from the surface. The rocks passed through were the following :—

	Feet.
Surface soil about	3
Shales, becoming gradually carbonaceous towards the base, about .	13
Hard carbonaceous sandstone, with many nests of iron pyrites, about .	4
Highly carbonaceous shales, with pyrites, about	10
Coal	Not passed through.

A good deal of water was met with in passing through the sandstone bed; and as the sappers and miners employed in sinking had no proper appliances for lifting the water, the sinking was a very slow process, and I stopped it as soon as coal was reached. The coal extracted is in a very different condition from that at the outcrop, being hard and compact, and not liable to be broken up by carriage to a distance. It is dull black in colour, with thin veins of brighter coal, and burns without flame in an open fire. The laboratory assay is :—

Moisture	·55
Volatiles, exclusive of moisture	11·48
Fixed Carbon	45·50
Ash	42·47
	100·00

Cakes, but not strongly. Ash, grey.

Pits were also driven into the seam, at Brehal and Ikni, to a depth of 20 feet from the surface, where they were stopped by water collecting in them. In these the quality of the coal showed no improvement, but they were not driven far enough to decide the question. The rocks at these places are more highly inclined and crushed than at Chakar, so that it is not likely that the coal would improve within so

short a distance from the outcrop as at that place. In the Bugoola valley,[1] the crushing was probably not so great; and here the coal in the interior of the seam would probably be found similar to that from Chakar.

II.—THE MEHOWGALA FIELD.

Distribution of the coal measures—In the valley of the Neari Tawi, a small stream running due south about 8 miles to the west of Sangar Marg, between the villages of Acker and Mehowgala, the *great limestone* is again brought up to the surface on the line of the sharp anticlinal north of Sujanpur, forming a dome-shaped mass in the centre of the valley, through which the Neari Tawi passes in a deep narrow gorge. The coal measures, with the overlying *Murree sandstone*, are exposed on all sides of this central mass, dipping away from it in every direction. The dip of the rocks is, as a rule, much less than in the Sangar Marg field; and if the coal seam were fairly constant in thickness, it could be worked under much more favourable conditions than in that area. Wherever the seam is exposed, however, it is found to be very irregular, sometimes thickening out within 30 or 40 feet, from 2 to 5 feet, and thinning as abruptly. At the same time, such lenticular beds of coal seem to be fairly numerous, and no doubt in the aggregate contain a large amount of coal.

The rocks forming the coal measures are of about the same total thickness as in the Sangar Marg field, as shown in the vertical section at the beginning of this report, but there are some changes in the minor beds. Thus the breccias at the base are absent, and the pisolitic clays overlying them are replaced by a hardened clay rock which is locally carbonaceous, and contains thin strings and lenticular beds of coal. These are well exposed at the village of Mehowgala itself, and on the paths leading down from it to the Neari Tawi. There are also two seams of coal about the horizon of the seam in the Sangar Marg area, with a thickness of about 20 feet of shale between them, but the upper seam is apparently never more than 2 feet thick and is generally less.

To the west of Mehowgala, the strata are so horizontal that the stream in the iro valley has cut down through the overlying *Murree sandstone*, and exposed the coal measures. The valley is a broad open one, and the upper portion of the coal measures occupy the greater part of its floor, but the horizon of the coal seams has been reached only near the head of the valley. Here the lower seam has a fairly

[1] NOTE.—Specimen from a pit near Bugoola gives:—

Moisture	·17
Volatiles, exclusive of moisture	8·67
Fixed Carbon	39·13
Ash	52·03

Cakes. Ash, light reddish-grey.

This and the above assay must be considered as very disappointing owing to the large quantity of ash: and if they could be relied on as indicating the average quality of the coal would be in themselves a death-blow to the hope of getting a serviceable fuel from this area. Such analyses, however, being made on a very small portion of the coal are apt to be misleading; and before condemning the whole seam, I would recommend that a sufficient quantity of coal for trial in a steam engine should be raised from the 10-foot pit at Bugoola, and sent down for experiment on the Jummu railway construction.

constant thickness of about 2 feet, with many lenticular beds of a greater thickness. One of these that I measured was about 60 feet long thickening from 2 feet at either end to 5 feet in the centre.

In the Neari Tawi valley, coal is exposed on the path leading from Acker down to the river, but here also it occurs in lenticular beds. In the bed of the river, the coal measures are concealed by gravels and boulder drift. In the vicinity of the central mass of limestone, both on the north and south, there is some local faulting, and the strata are a good deal disturbed; but further up and down stream, the dip settles down more regularly to the north and south respectively. Borings might be made, say, ½ mile from either end of the narrow gorge, to find the depth of the seam.

Condition of the Coal.—At the outcrop the coal is in the same flaky and friable condition as at Sangar Marg, but as the rocks have undergone very little folding, it no doubt improves in the interior of the seam.

The Golan Stream.—Between the Sangar Marg and Mehowgala fields, the coal measures are brought to the surface in the narrow valley of the Golan stream about a mile above the place where the path from Kotla to Mehowgala crosses it. The horizon of the coal seam is not exposed, the lowest rock seam being the lower band of nummulitic limestone, which forms a dome-like ridge on the right (W.) bank of the stream, but a boring of no great depth would reach the coal if present. The rocks, however, are much folded, and the coal could not be worked to any great distance.

GENERAL REMARKS.

It would be very difficult to give a satisfactory estimate of the total quantity of coal available in these fields, at any rate until the thickness of the seam has been horoughly tested by boring; and I shall not attempt to do so. My opinion is that here is a large amount of coal, but spread over so large an area that the average hickness of the seam is not great. Whether it would be profitable to work a seam nly 2 or 3 feet in average thickness, must depend on the demand for coal in the 'unjab, and the distance of the nearest railway line. A large initial outlay would ave to be incurred in any case in making borings and sinking pits on a European ystem before any coal could be extracted, as it would be very unadvisable to work e coal from the outcrops, as might be done if the strata were more horizontal.

As it is impossible to mark the sites I have selected for borings in so small a nap as the 2 miles= 1 inch which is the largest at present available, I append a ble giving a list of the different places in which borings might be made, with the ocks exposed at the surface in which the borings would be commenced, and the ip of the rocks. Most of these I marked in the field with a small cairn of stones s a guide to the engineer who will superintend the borings. These are marked ith an asterisk. As a rule, I have chosen them in such places that the coal should e reached at a moderate depth; but afterwards, if these are successful, other orings might be made at greater distances from the outcrop. In any case, the orings I have indicated should, I think, be made before any expense is incurred in inking pits.

List of Boring Sites.

Sangar Marg Field.

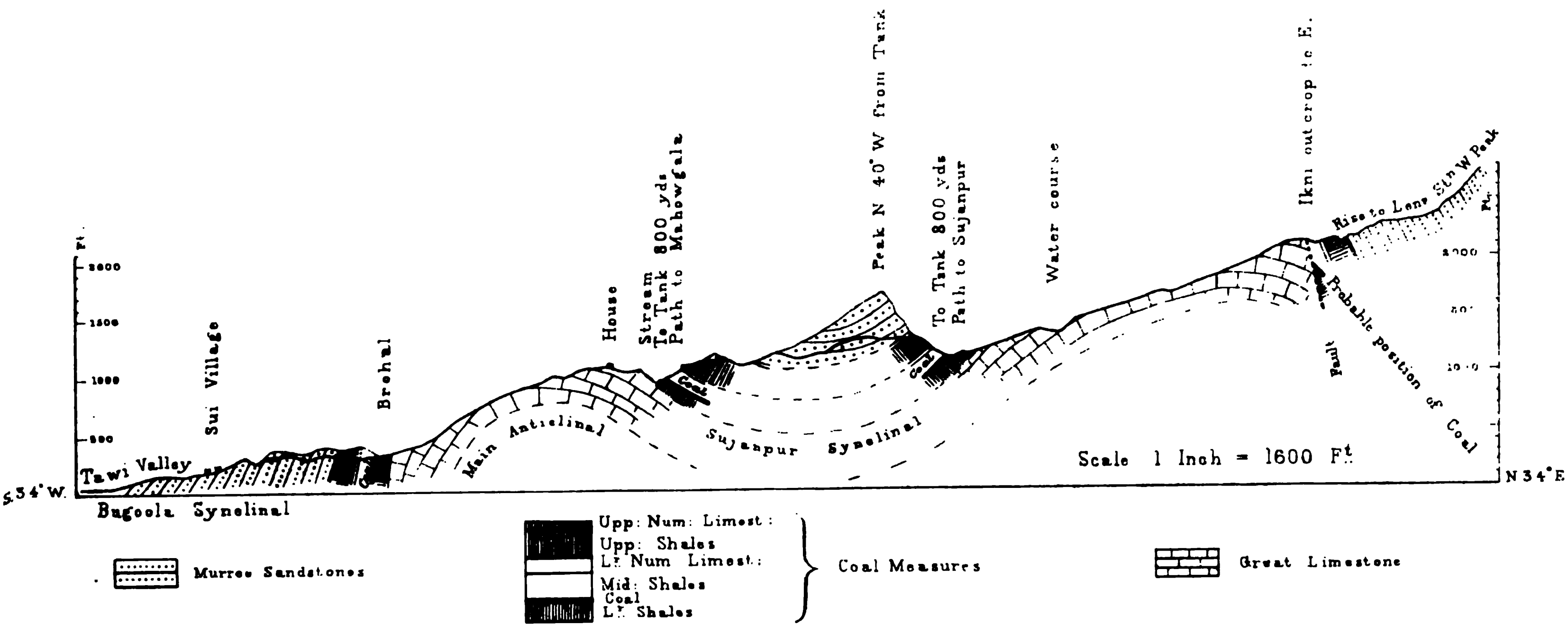
Locality.	Beds exposed at surface.	Direction of dip.	Angles of dip.	Remarks.
1* Kroli village, at side of path on *col* leading to Tawi valley.	C.M. upper shales	S.W.	67°	Coal exp. about 80 ft. to N.
2. Kahiar village, in ravine to E. of village.	M.S.S.	S. 20° W.	62°	
3* About 500 yards S. of Ransu village, on path from Berh to Kotla at side of small stream.	M.S.S.	?	?	Rocks at surface not well exp.
4. Near conical hollow on fields about 200 yards S.W. of Ransu.	......	...	...	Rocks concealed by cultivation.
5. In bed of Tawi stream by 2nd mill below gorge at Ransu.	......	...	...	Rocks concealed by boulders in river.
6* Bugoola valley, about 300 yards S.W. of Kori, Gulabgarh fort W. 7° N.	M.S.S.	S.	50°	
7* Between Kori and Ransu, about 30 ft. S. of path on top of *col*.	C.M. middle shales.	S.	40°	
8. Brehal side of stream about 100 yards S. of coal outcrops.	C.M. upper shales	S.	70°	
9* Chakar in ravine about 500 yards W. of tank, Lena Stn. N. 30° E.	C.M. lower portion of upper shales.	N. 20° E.	30°	
10* Chakar, about 300 yards N. of tank, Lena stn. N. 25° E. Peak above Berh S. 35° W.	Do. do. do.	Approx. h	orizontal.	

Mehowgala Field.

Locality.	Beds exposed at surface.	Direction of dip.	Angles of dip.	Remarks.
11* In valley N. of Acker village, about 1½ miles from Neari Tawi Mehowgala due W.	C.M. near top of upper shales.	S. 25° E.	44°	
12* In bed of Neari Tawi, about 100 yards below crossing of path from Acker to Mehowgala.	C.M. top of middle shales.	S.	36°	
13* W. of Mehowgala village, where path to Siro turns S. along base of scarp of M.S.S.	Base of M.S.S.	W.N.W.	6°	
14* In ravine on path to Siro from Mehowgala.	C.M. top of upper shales.	Approx. h	orizontal	.
15* In same ravine E. of Siro village	C.M. upper shales	Do.		
16* On left bank of Siro stream below the village near junction with small stream from W.	C.M. upper shales	S.S.W.	17°	
17* About ½ mile W. of Siro village in valley of small tributary stream.	C.M. upper shales	Approx. h	orizontal	.

M.S.S. = *Murree Sandstones.* C. M. = *Coal measures.*
N.B.—The bearings throughout are *compass bearings.*

SECTION ACROSS SANGAR MARG COAL FIELD FROM BREHAL TO LENA STN.



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Thirteen specimens of *physa* from Nagpur.
PRESENTED BY B. V. ROYDU, MAHARAJA, NAGPUR.

Limestone from Birds' Nest or Elephant Island caves, South-East of Domel Island, Mergui Archipelago. PRESENTED BY COMMANDER A. CARPENTER, R.N., H. M. I. M. S., "INVESTIGATOR." PORT BLAIR.

Graphitic shale (containing 19·33°/₀ carbon), and carbonate of lime, from near Rampur, on the Murree-Kashmir Road.
PRESENTED BY E. S. FARRANT, C.E., EXECUTIVE ENGINEER TO THE RESIDENT IN KASHMIR.

Fossils (proboscidian) found on a hill above the village of Khyrabad in the Salt Range, a few miles from Mari, Kalabagh, Punjab.
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Four specimens of crystalline rocks, from different localities, collected during a trip from Mussoorie to Gangutri. PRESENTED BY DR. H. WARTH.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1888. **[August.**

The Manganese-iron *and* Manganese-ores *of* Jabalpur, *by* PRAMATHA NATH BOSE, B.Sc., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With 2 maps.)[1]

The *pyrolusite* of Gosalpur was first brought to the notice of Government by Mr. W. G. Olpherts in 1875. It was examined in 1879 by Mr. H. B. Medlicott, late Director of the Geological Survey, and a note on the ore, with an analysis of it by Mr. Mallet, was published in the "Records" of the Survey for that year (Vol. XII, p. 99). Four years later Mr. Mallet examined the iron-ores of the northern portion of the district of Jabalpur. In his very valuable and comprehensive paper on those ores ("Records," Vol. XVI), there is a brief notice of the Manganese-ores of Gosalpur. He was, I believe, the first to point out the existence of *psilomelane* in association with manganiferous hematite, the latter forming a band in the Lora group[2] at Gosalpur and Khatola.

In 1884 Mr. C. W. McMinn, then Deputy Commissioner of Jabalpur, sank a number of pits to ascertain the extent of the manganese-ores at Gosalpur. In the same year Dr. King, the present Director of the Survey, paid a hurried visit to the place from Jabalpur. During the Durga Puja holidays last year, the ores were further explored by Mr. E. J. Jones of the Geological Survey. After Mr. Jones' return, I was deputed by the Director about the middle of October last to continue the exploration.

On arrival at Gosalpur, I found a number of pits and trenches excavated by Messrs. McMinn and Jones, of which Mr. McMinn's pits had been partially filled up. I had these cleaned, and, where necessary, deepened, and started a number of fresh excavations in different parts of the village. I found that the *pyrolusite* occurred in

[1] Map 1 only published now: Map 2 will appear in next number of the Records.

[2] One of the groups into which the Bijawar formation has been divided, called after the Lora range near Sihora. (*Vide* Records, Vol. XVI, p. 96.)

and among quartzites,[1] which were subsequently found to invariably accompany the Lora group, forming probably its base, and which, for the sake of convenience, I have designated as Gosalpur quartzites. I found, also, that the Lora group formed a distinct synclinal just west of Gosalpur, the manganiferous and other Lora strata which crop out here re-appearing in the Chakrandha hill, a mile and a half west of Gosalpur, but with the dip reversed. With these clues I traced the *psilomelane* and *pyrolusite* over a rather wide area, included partly in Sihora and partly in Jabalpur Tahsil. But though spread over such a large area, the quantity of *pyrolusite* does not appear to be so great as might be expected. I must observe, however, that none of the localities was searched so minutely as Gosalpur; and that the present report is to be taken rather as indicating the directions in which *pyrolusite* or *psilomelane* is to be looked for, than as giving an exact, or even an approximately exact, estimate of the ore-bearing capabilities of the entire area. However, enough has, I venture to think, been done for exploration purposes in the northern portion of the Bijawar ground. With regard to the southern Bijawar ground, west and south-west of Jabalpur, I had time only to pay a hurried visit to it. I found *psilomelane* in the Lora group at Nonsar, 12 miles north-north-west of Jabalpur, on the road to Patun. The Lora group also occurs at Gangai (a short distance south of the Marble Rocks near Jabalpur); and it is possible that both *pyrolusite* and *psilomelane* will be found in it. I would recommend that the unspent portion of the manganese exploration fund, amounting to R75-7, be devoted to the exploitation of this area.

The Central Provinces Government made a grant of R500 for the manganese exploration at Gosalpur. When I found that the ores extended far beyond this place, I tried, by exercising strict economy, to make my work cover the entire area without exceeding the grant; R450 only was drawn by me, and of this amount an unspent balance of R25-7 has been deposited with the Deputy Commissioner of Jabalpur.

I have to record my thanks to Messrs. C. W. McMinn and F. C. Anderson, Commissioner and Deputy Commissioner, respectively, of Jabalpur, when I started work, for the readiness with which they gave me every assistance that lay in their power. The Director paid an inspection visit while the exploration was in progress; and if it may be called successful in any sense, not a little of the success is owing to his guidance and encouragement.

I have in this report tried to present the economic results of the exploration. Observations which are chiefly of theoretical interest will be discussed in a separate report which will be submitted to the Director later on.

I. MANGANIFEROUS HEMATITE AND PSILOMELANE.

A. MANGANIFEROUS HEMATITE.

[illegible] is confined almost exclusively to the Lora group. [illegible] will be specially noticed hereafter. The [illegible] to be that known as micaceous-iron-ore, [illegible] quartzites both contorted together,

[1] [illegible] see p. 82.

and the former curiously following the flexures (which are sometimes very sharp) of the latter.

The micaceous-iron-banded quartzite, *i.e.*, quartzite with interbedded layers of micaceous hematite, is generally too poor to be worked profitably. But at places the micaceous-iron-ore is very rich, the quartzite element being entirely, or almost entirely, wanting. This richness usually takes place on comparatively low ground. The highest points of the ridges are almost invariably formed of contorted quartzites with layers of micaceous hematite.

When the micaceous-iron-ore is very rich, as at the foot of Santok hill (Gosalpur), the rock may be called a micaceous-hematite schist. Such micaceous-hematite schist was seen in the direction of the strike, as well as across it, to pass into the folded quartzose rocks with thin layers of the ore at Dharampur and elsewhere.

The micaceous hematite sometimes passes almost imperceptibly into manganiferous hematite, which appellation is here given to hematite in which the presence of manganese is discernible with the naked eye, for there can be hardly any doubt that this mineral is also present in the micaceous hematite, though as mere traces. In proportion as the micaceous-iron-ore becomes manganiferous, it loses its characteristic micaceous lustre, and becomes more earthy-looking and massive. The shales interstratified with, and overlying, or underlying, the micaceous-iron-banded quartzites are also frequently impregnated with manganiferous hematite in varying degrees of richness.

The manganese in the manganiferous hematite is usually present as nests and thread-like veins of *psilomelane*, besides being disseminated in the matrix.

In the Lora hill area (in which I include the entire area stretching from Daimapur to Murhasan), manganiferous hematite in workable quantity was found at the following localities:—

I.—*Dharampur (including Hirdenagar)*.—Close to the boundary between this village and Deonagar, on the western slope of the ridge running south-west from Gosalpur, a trench exhibited the following section (commencing at the north-western end):—

8′ Soft whitish talcose slaty shales *(chuhi)* dipping north-north-west.
18′ Obscured.
11′ Shales.
18′ Obscured.
32′ Decomposed earthy rocks with traces of micaceous hematite.
24′ Obscured.
13′ Whitish shales with a little micaceous hematite.
28′ Shaly and quartzose rocks with some micaceous-iron-ore.
15′ Micaceous hematite.
3′ Banded jaspery-looking rock, with limonite towards surface, dipping N. 35 W.
6′ Obscured.
78′ Soft, thinly-stratified, whitish and yellowish talcose shales.
13′ Obscured.
32′ Micaceous manganiferous hematite.
10′ Shales impregnated with *psilomelane*.

A trench three-quarters of a mile north-east of this trench, on the road from

Tola Hirdenagar to Dharampur showed the following section, commencing at the north-western end (about 57 feet from it):—

12' Massive limonite, with segregated *psilomelane* at the surface.
5' Shaly rocks.
12' Shaly rocks (rather thick-bedded) with some manganiferous hematite.
33' Shales (partly obscure).
6' Manganiferous hematite with *psilomelane*.
16' Shales with a little micaceous iron-ore.
17' Manganiferous hematite.
12' Soft, decomposed, earthy rocks, with micaceous iron-ore.
25' Soil to a depth of 4' with fragments of micaceous iron, manganiferous hematite, &c.
6' Obscured.

A trench about three-quarters of a mile east of the village of Dharampur, and close to the boundary between it and Murta (a deserted village), exhibited a rather rich deposit of manganiferous hematite. Commencing from the north-western end the cross cut gives the following section:—

28' Micaceous-iron-banded quartzite (poor).
4' Manganiferous hematite (with massive *psilomelane* at the surface).
88' Micaceous iron-banded quartzite (poor).
30' Schistose micaceous iron (rather rich).
14' Micaceous-iron-banded quartzite.
8' Obscured.
2' Schistose micaceous iron (rich) apparently much 'crushed,' with abundant *psilomelane*. [The dip observed so far points N.N.W.]
12' Obscured.
11 Manganiferous hematite, very rich in *psilomelane*, apparently much crushed.
33 Micaceous hematite at places rich in *psilomelane*.

A pit dug at this end showed (from the surface)—

20' Large blocks of apparently much crushed manganiferous hematite with abundant *psilomelane*.
3' Schistose micaceous iron with a little *psilomelane*.

Another pit, 24 feet south-east of last showed from the surface—

20' Large blocks of *psilomelane*.
20' Large blocks of *psilomelane* (but harder) with bits of micaceous hematite.
4' Schistose micaceous hematite.

II. Gowaipur.—A cross-cut here, a little less than half a mile north-west of the dâk bungalow, gave the following section, commencing a few feet from the north western end:—

6' Manganiferous hematite (very rich). *Psilomelane* in large botryoidal masses at the surface.
13' Manganiferous hematite gradually becoming poorer, southward.
5' Obscured.
18' Soft micaceous iron-ore.
8' Micaceous-iron-banded quartzite. [The dip so far appears very high and points to N.N.W. to N.W.]

25′ Obscured.

43′ 'Crushed' quartzoze rocks with manganiferous hematite, rather rich at places.

8′ Micaceous-iron-banded quartzite.

43′ Schistose micaceous hematite with a little *psilomelane*, dipping N.N.W. 60°.

The cross-cut at the northern edge of the ridge north-west of the dâk bungalow, locally known as Santok hill, about a quarter of a mile north of the bungalow, gave a good section. The trench was dug partly by Mr. McMinn and partly by Mr. Jones. It was deepened by me at places. Commencing at the north-western end the section is as follows :—

7′ Reddish and purplish slaty shales, dipping 55° N.W. by N.

4′ Manganiferous hematite with thin veins of *psilomelane*. The surface of the hematite bed is botryoidal at places, the *psilomelane* veins following the contour of the concretions.

35′ Soft, talcose shales, at places impregnated with iron-ore.

28′ Schistose, micaceous hematite.

8′ Same as above, but blacker, more massive-looking, richer, and with occasional veins and nests of *psilomelane*.

12′ Schistose micaceous hematite.

8′ Micaceous hematite partly with veins and nests of *psilomelane*.

22′ Argillaceous rocks, with some micaceous hematite.

42′ Mottled quartzose rocks more or less obscured at places.

III.—At Pahrewa (a mile and a half south of Sihora) and at Khatola, the manganiferous iron-ore is fairly rich at places. Close to the boundary between Sukra (a deserted village just east of Khatola) and Surda, a trench gave the following section, proceeding from its north-western end :—

230′ Manganiferous hematite, very rich at places.

24′ Covered up.

21′ Manganiferous hematite.

27′ Obscured.

15′ Schistose micaceous hematite.

8′ Obscured.

17′ Micaceous-iron-banded quartzites, much folded and crumpled.

IV. Gogra.—Along the southern slope of the Lora range the manganiferous ore is very rich at places. It is especially so at Gogra, close to, and at, the boundary between this village and Danwai. There are some mines here which have for some time past been supplying the furnaces of the entire neighbourhood.

V.—Mangela (a deserted village).—Here, too, the ore appears to be rather rich. There are some old mines here.

With regard to the other outcrops of the Lora group, manganiferous hematite does not appear to be present, at least to any considerable extent, in the band stretching from south of Chattarpur to Saroli, as well as in the Lamehra range of hills. I am not also aware of its occurrence in the outcrop south-west of Bhera Ghat. Neither of these bands, however, was closely searched.

In the Lora patch at Nonsar (12 miles north-west of Jabalpur, on the road to Patan) manganiferous hematite was found to exist.

manganese-ore were found along hill slopes, but the search for the ore *in situ* from which the blocks may have been derived proved fruitless.

The quartzose strata after an interspace of about a mile re-appear north-east of Darsani, richly impregnated with *psilomelane* and other manganese-ores. They form a ridge running in the direction of strike for about 2 miles. The manganese and iron-ores here are very much mixed together. The former predominate in the hill just north-east of Darsani, as also on Kasai (or Kushi) hill. A pit opened on the south-eastern slope of the former exhibited some 16 feet of the ore, which appears to be mostly *psilomelane*. In the Kushi hill a distinct syncline was observed. This hill will be again noticed in connection with *pyrolusite*. The quartzose strata of Ponri, Darsani, and Kushi hill probably belong to the Lora group, and have, in all likelihood, come up by an anticlinal flexure.

A large quantity of *psilomelane* in the form of nodules occurs at Gosalpur (Area *b*, Map of Gosalpur). And a little of the mineral in intimate association with *pyrolusite* also occurs at this place and elsewhere.

From the mode of occurrence of *psilomelane* it is impossible to form anything like an estimate of the quantity present. The quantity of pure *psilomelane* cannot be very great, as it is chiefly confined to the surface. Still it is probably greater than that of *pyrolusite*. The quantity of manganiferous hematite, with veins and nests of *psilomelane*, must, however, be regarded as practically inexhaustible.

An assay of an average specimen of the manganiferous hematite (from Danwai mine) made by Mr. Mallet, gave the following result (Rec., Vol. XVI, p. 101):—

Ferric oxide	66·33	= Iron 46·43
Manganese (with traces of cobalt)	12·26	
Oxygen	6·83	
Phosphoric acid	·27	
Sulphuric acid	·03	
Sulphur	trace	
Ignited insoluble residue	9·55	
Lime, alumina, water and undetermined	4·76	
	100·03	

The ore would be useful for the manufacture of steel. At present it is used for the manufacture of a kind of a steely iron, known as *kheri*. A brief account of the *kheri* industry will be found in Note A.

A specimen of *psilomelane* analysed by Mr. Mallet yielded 83·20 per cent. of the available peroxide.

II.—PYROLUSITE.

Its distribution is generally co-extensive with that of the Gosalpur quartzites.[1] At places, however, the mineral is present as mere traces. It was found in any quantity at the following localities:—

1. *Gosalpur*—Except in the ground just in front of the dâk bungalow (some 50 yards to south-east of it), the *pyrolusite* occurs here in and among the Gosalpur quartzites, usually soft, decomposed, and blue-coated at the outcrop. Sometimes the rock is hard, and either white or red in colour, assuming in the latter case the

[1] A band underlying, and probably forming the base of, the Lora group.

appearance of jasper. Wherever such is the case, manganese-ores are wanting. Frequently the rock appears as a conglomerate or breccia, fragments of soft, decomposed (sometimes almost powdery) quartzite being cemented together, as it were, by a matrix of *manganese* or iron-ore. Wherever such a rock crops out, *manganese* or iron-ore is found in some quantity by digging close to it through the soil-cap under which it passes, the nature of the ore being determined by that of the "matrix" at the outcrop.

The quartzites have the general Bijawar strike of the area, *viz*., N.E.-S.W., The dip is obscure; it was found to be very high (about 80°) pointing S.E., some 150 yards north of the dâk bungalow.

The details of some of the sections as exposed by the pits (see Map of Gosalpur) at this place may not be uninteresting. The great majority of them may be grouped in two lines, 250 to 500 feet apart, running nearly E.—W., roughly parallel to each other.

Commencing with Pit No. XIII, at the western extremity of the southern line of pits, the sections are as follows :—

Pit XIII.

1 0' Soil with grains and nodules of iron-ore.

6' Large blocks of hematite, some with fragments of decomposed quartz rock passing below into decomposed quartzites with veins of hematite.

Pit XIV.—One hundred and seventy-five feet east-north-east of last pit. It is an old, large, squarish pit, measuring 25 feet east to west. At its northern end there is an outcrop of the Gosalpur quartzites, either coated blue or having the appearance of a "breccia," such as has been described above. The pit was deepened at two ends to 30 feet at the western, and 12 feet at the eastern end.

1' Soil with blocks of quartzite.

1' Grains and nodules of iron-ore, with a few occasional grains of *pyrolusite* and fragments of quartzite.

5 0' Abundant *psilomelane* in flat platy masses, with which are associated *pyrolusite* and hematite as grains and nodules.

The shaft at the western end of the pit disclosed below the last-mentioned layer a thickness of—

22 0' of decomposed, rotten, crumbly, whitish, yellowish, and mottled speckled quartz-rock with veins and nests of *pyrolusite*, passing below into similar decomposed speckled rock, but without these veins and nests. Small pockets of well-crystallised *pyrolusite* were found, however, in the latter at various depths. The speckled appearance is due to the presence of brownish specks, which will be described hereafter.

Pit XIX.—Two hundred and twenty-five feet to east of last—

6' Soil.

3 0' Platy, flat and botryoidal masses of *psilomelane*, with some *pyrolusite* (the former predominating largely), and grains and nodules of iron-ore.

4' Decomposed yellowish and mottled quartz-rock, with veins and nests of *pyrolusite* and *psilomelane*.

Pit XV.—Fifty feet east of last—

1' Soil.

4′ Nodules and grains of iron-ore, and of *pyrolusite* largely associated with *psilomelane.*

4′6″ Yellowish decomposed quartz-rock with nodules of earthy-looking *pyrolusite* (?).

3′ Yellowish, decomposed, quartz-rock, with veins and nests of *pyrolusite* (?), which disappear towards bottom.

Pit III.—Two hundred feet east-south-east of last—

1′ Soil.

6″ Nodules and grains of iron-ore, with a little *pyrolusite* towards base.

3′ Grains and nodules of iron-ore and of *pyrolusite*, the latter measuring ⅛″ to 2″ across, and associated with *psilomelane* (but not so largely as in the previous pits).

3′6″ Decomposed quartz-rocks with grains and nodules of *pyrolusite.*

Pit XXVIII.—One hundred feet east of last—

3′ Soil.

2′6″ Nodules and grains of *pyrolusite* and of iron-ore, the former averaging probably less than ½ inch in diameter.

1′ Large blocks of very good *pyrolusite*, somewhat spongy in texture, with cavernous spaces occupied by yellowish, decomposed quartz-rock.

1′2″ Decomposed yellowish and yellowish-white mottled quartz-rock, with veins and nests of *pyrolusite.*

Pit XXXI.—One hundred and ten feet east of last.—This is one of three pits sunk in a large, old, partially filled-up pit, from which *pyrolusite* used to be raised of old by glass-makers.

2′ Soil.

2′8″ Abundant nodules of *pyrolusite*, ¼ inch to 6 inches in diameter, mixed up, as usual, with nodules of iron-ore. A little *psilomelane* and *wad* occurs in association with the *pyrolusite.*

4′10″ Fragments of decomposed yellowish, and yellowish-white, mottled quartz-rock, becoming larger and more abundant towards bottom. *Pyrolusite* occurs in the interstices in larger blocks than in the preceding stratum and with cavernous spaces containing the decomposed quartz-rock.

Decomposed quartz-rock with veins and nests of *pyrolusite.*

Pit XLVI.—Seventy-five feet south-east of last—

2′4″ Grains and nodules of iron-ore.

3′10″ Yellowish and brown mottled ferruginous grit, or gritty clay, in large blocks.

6″ Spongy nodules of *pyrolusite* with decomposed quartzite.

Pit XLVII.—Fifty feet south-east of last—

9′ Yellowish and brown ferruginous grit, or gritty clay, without a trace of *pyrolusite.* The rock was found so hard that it had to be blasted.

Pit XXV.—Five hundred feet east-north-east of last, in the Bazar.

3′ Soil.

4′4″ Hard, yellowish loam, with grains of *pyrolusite* and iron-ore.

12′ Nodules and grains of iron-ore, at places compacted into large, hard blocks with abundant oolitic grains (internally black, *pyrolusite* ?), and a few large nodules of hematite and of *pyrolusite.*

Titles of Books. *Donors.*

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April 16th, 1888.

Government of India Central Printing Office.—No. 30 D. G. Survey.—2-6-88.—720.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1888. **[August.**

The Manganese-iron *and* Manganese-ores *of* Jabalpur, *by* PRAMATHA NATH BOSE, B.Sc., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With 2 maps.)[1]

The *pyrolusite* of Gosalpur was first brought to the notice of Government by Mr. W. G. Olpherts in 1875. It was examined in 1879 by Mr. H. B. Medlicott, late Director of the Geological Survey, and a note on the ore, with an analysis of it by Mr. Mallet, was published in the "Records" of the Survey for that year (Vol. XII, p. 99). Four years later Mr. Mallet examined the iron-ores of the northern portion of the district of Jabalpur. In his very valuable and comprehensive paper on those ores ("Records," Vol. XVI), there is a brief notice of the Manganese-ores of Gosalpur. He was, I believe, the first to point out the existence of *psilomelane* in association with manganiferous hematite, the latter forming a band in the Lora group[2] at Gosalpur and Khatola.

In 1884 Mr. C. W. McMinn, then Deputy Commissioner of Jabalpur, sank a number of pits to ascertain the extent of the manganese-ores at Gosalpur. In the same year Dr. King, the present Director of the Survey, paid a hurried visit to the place from Jabalpur. During the Durga Puja holidays last year, the ores were further explored by Mr. E. J. Jones of the Geological Survey. After Mr. Jones' return, I was deputed by the Director about the middle of October last to continue the exploration.

On arrival at Gosalpur, I found a number of pits and trenches excavated by Messrs. McMinn and Jones, of which Mr. McMinn's pits had been partially filled up. I had these cleaned, and, where necessary, deepened, and started a number of fresh excavations in different parts of the village. I found that the *pyrolusite* occurred in

[1] Map 1 only published now: Map 2 will appear in next number of the Records.

[2] One of the groups into which the Bijawar formation has been divided, called after the Lora range near Sihora. (*Vide* Records, Vol. XVI, p. 96.)

and among quartzites,[1] which were subsequently found to invariably accompany the Lora group, forming probably its base, and which, for the sake of convenience, I have designated as Gosalpur quartzites. I found, also, that the Lora group formed a distinct synclinal just west of Gosalpur, the manganiferous and other Lora strata which crop out here re-appearing in the Chakrandha hill, a mile and a half west of Gosalpur, but with the dip reversed. With these clues I traced the *psilomelane* and *pyrolusite* over a rather wide area, included partly in Sihora and partly in Jabalpur Tahsil. But though spread over such a large area, the quantity of *pyrolusite* does not appear to be so great as might be expected. I must observe, however, that none of the localities was searched so minutely as Gosalpur; and that the present report is to be taken rather as indicating the directions in which *pyrolusite* or *psilomelane* is to be looked for, than as giving an exact, or even an approximately exact, estimate of the ore-bearing capabilities of the entire area. However, enough has, I venture to think, been done for exploration purposes in the northern portion of the Bijawar ground. With regard to the southern Bijawar ground, west and south-west of Jabalpur, I had time only to pay a hurried visit to it. I found *psilomelane* in the Lora group at Nonsar, 12 miles north-north-west of Jabalpur, on the road to Patun. The Lora group also occurs at Gangai (a short distance south of the Marble Rocks near Jabalpur); and it is possible that both *pyrolusite* and *psilomelane* will be found in it. I would recommend that the unspent portion of the manganese exploration fund, amounting to R75-7, be devoted to the exploitation of this area.

The Central Provinces Government made a grant of R500 for the manganese exploration at Gosalpur. When I found that the ores extended far beyond this place, I tried, by exercising strict economy, to make my work cover the entire area without exceeding the grant; R450 only was drawn by me, and of this amount an unspent balance of R25-7 has been deposited with the Deputy Commissioner of Jabalpur.

I have to record my thanks to Messrs. C. W. McMinn and F. C. Anderson, Commissioner and Deputy Commissioner, respectively, of Jabalpur, when I started work, for the readiness with which they gave me every assistance that lay in their power. The Director paid an inspection visit while the exploration was in progress; and, if it may be called successful in any sense, not a little of the success is owing to his guidance and encouragement.

I have in this report tried to present the economic results of the exploration. Observations which are chiefly of theoretical interest will be discussed in a separate report, which will be submitted to the Director later on.

I. MANGANIFEROUS HEMATITE AND PSILOMELANE.

A.—MANGANIFEROUS HEMATITE.

The manganiferous hematite is confined almost exclusively to the Lora group. There is one doubtful occurrence, which will be specially noticed hereafter. The normal and original form of the ore appears to be that known as micaceous-iron-ore, layers of which are interbanded with thin jaspery quartzites, both contorted together,

[1] There is one exception, see p. 82.

nd the former curiously following the flexures (which are sometimes very sharp) f the latter.

The micaceous-iron-banded quartzite, *i.e.*, quartzite with interbedded layers of iicaceous hematite, is generally too poor to be worked profitably. But at places the iicaceous-iron-ore is very rich, the quartzite element being entirely, or almost ntirely, wanting. This richness usually takes place on comparatively low ground. 'he highest points of the ridges are almost invariably formed of contorted quartzites 'ith layers of micaceous hematite.

When the micaceous-iron-ore is very rich, as at the foot of Santok hill (Gosalpur), ıe rock may be called a micaceous-hematite schist. Such micaceous-hematite chist was seen in the direction of the strike, as well as across it, to pass into the ɔlded quartzose rocks with thin layers of the ore at Dharampur and elsewhere.

The micaceous hematite sometimes passes almost imperceptibly into mangani-ɜrous hematite, which appellation is here given to hematite in which the presence of aanganese is discernible with the naked eye, for there can be hardly any doubt that his mineral is also present in the micaceous hematite, though as mere traces. In roportion as the micaceous-iron-ore becomes manganiferous, it loses its character-stic micaceous lustre, and becomes more earthy-looking and massive. The shales nterstratified with, and overlying, or underlying, the micaceous-iron-banded quart-ites are also frequently impregnated with manganiferous hematite in varying degrees f richness.

The manganese in the manganiferous hematite is usually present as nests and hread-like veins of *psilomelane*, besides being disseminated in the matrix.

In the Lora hill area (in which I include the entire area stretching from Daima-ur to Murhasan), manganiferous hematite in workable quantity was found at the ɔllowing localities:—

I.—*Dharampur (including Hirdenagar)*.—Close to the boundary between this illage and Deonagar, on the western slope of the ridge running south-west from ;osalpur, a trench exhibited the following section (commencing at the north-west-rn end):—

8′ Soft whitish talcose slaty shales *(chuhi)* dipping north-north-west.
18′ Obscured.
11′ Shales.
18′ Obscured.
32′ Decomposed earthy rocks with traces of micaceous hematite.
24′ Obscured.
13′ Whitish shales with a little micaceous hematite.
28′ Shaly and quartzose rocks with some micaceous-iron-ore.
15′ Micaceous hematite.
3′ Banded jaspery-looking rock, with limonite towards surface, dipping N. 35 W.
6′ Obscured.
78′ Soft, thinly-stratified, whitish and yellowish talcose shales.
13′ Obscured.
32′ Micaceous manganiferous hematite.
10′ Shales impregnated with *psilomelane*.

A trench three-quarters of a mile north-east of this trench, on the road from

Tola Hirdenagar to Dharampur showed the following section, commencing at the north-western end (about 57 feet from it):—

12′ Massive limonite, with segregated *psilomelane* at the surface.
5′ Shaly rocks.
12′ Shaly rocks (rather thick-bedded) with some manganiferous hematite.
33′ Shales (partly obscure).
6′ Manganiferous hematite with *psilomelane.*
16′ Shales with a little micaceous iron-ore.
17′ Manganiferous hematite.
12′ Soft, decomposed, earthy rocks, with micaceous iron-ore.
25′ Soil to a depth of 4′ with fragments of micaceous iron, manganiferous hematite, &c.
6′ Obscured.

A trench about three-quarters of a mile east of the village of Dharampur, and close to the boundary between it and Murta (a deserted village), exhibited a rather rich deposit of manganiferous hematite. Commencing from the north-western end the cross-cut gives the following section:—

28′ Micaceous-iron-banded quartzite (poor).
4′ Manganiferous hematite (with massive *psilomelane* at the surface).
88′ Micaceous-iron-banded quartzite (poor).
30′ Schistose micaceous iron (rather rich).
14′ Micaceous-iron-banded quartzite.
8′ Obscured.
2′ Schistose micaceous iron (rich) apparently much 'crushed,' with abundant *psilomelane.* [The dip observed so far points N.N.W.]
12′ Obscured.
11′ Manganiferous hematite, very rich in *psilomelane,* apparently much crushed.
33′ Micaceous hematite at places rich in *psilomelane.*

A pit dug at this end showed (from the surface)—

2′6″ Large blocks of apparently much crushed manganiferous hematite with abundant *psilomelane.*
3′ Schistose micaceous iron with a little *psilomelane.*

Another pit, 24 feet south-east of last showed from the surface—

2′6″ Large blocks of *psilomelane.*
2′6″ Large blocks of *psilomelane* (but harder) with bits of micaceous hematite.
4′ Schistose micaceous hematite.

II. Gosalpur.—A cross-cut here, a little less than half a mile north-west of the dâk bungalow, gave the following section, commencing a few feet from the north-western end:—

6′ Manganiferous hematite (very rich). *Psilomelane* in large botryoidal masses at the surface.
13′ Manganiferous hematite gradually becoming poorer, southward.
5′ Obscured.
18′ Soft micaceous iron-ore.
8′ Micaceous-iron-banded quartzite. [The dip so far appears very high and points to N.N.W. to N.W.]

25′ Obscured.

43′ 'Crushed' quartzoze rocks with manganiferous hematite, rather rich at places.

8′ Micaceous-iron-banded quartzite.

43′ Schistose micaceous hematite with a little *psilomelane*, dipping N.N.W. 60°.

The cross-cut at the northern edge of the ridge north-west of the dâk bungalow, locally known as Santok hill, about a quarter of a mile north of the bungalow, gave a good section. The trench was dug partly by Mr. McMinn and partly by Mr. Jones. It was deepened by me at places. Commencing at the north-western end the section is as follows :—

7′ Reddish and purplish slaty shales, dipping 55° N.W. by N.

4′ Manganiferous hematite with thin veins of *psilomelane*. The surface of the hematite bed is botryoidal at places, the *psilomelane* veins following the contour of the concretions.

35′ Soft, talcose shales, at places impregnated with iron-ore.

28′ Schistose, micaceous hematite.

8′ Same as above, but blacker, more massive-looking, richer, and with occasional veins and nests of *psilomelane*.

12′ Schistose micaceous hematite.

8′ Micaceous hematite partly with veins and nests of *psilomelane*.

22′ Argillaceous rocks, with some micaceous hematite.

42′ Mottled quartzose rocks more or less obscured at places.

III.—At Pahrewa (a mile and a half south of Sihora) and at Khatola, the manganiferous iron-ore is fairly rich at places. Close to the boundary between Sukra (a deserted village just east of Khatola) and Surda, a trench gave the following section, proceeding from its north-western end :—

230′ Manganiferous hematite, very rich at places.

24′ Covered up.

21′ Manganiferous hematite.

27′ Obscured.

15′ Schistose micaceous hematite.

8′ Obscured.

17′ Micaceous-iron-banded quartzites, much folded and crumpled.

IV. Gogra.—Along the southern slope of the Lora range the manganiferous ore is very rich at places. It is especially so at Gogra, close to, and at, the boundary between this village and Danwai. There are some mines here which have for some time past been supplying the furnaces of the entire neighbourhood.

V.—Mangela (a deserted village).—Here, too, the ore appears to be rather rich. There are some old mines here.

With regard to the other outcrops of the Lora group, manganiferous hematite does not appear to be present, at least to any considerable extent, in the band stretching from south of Chattarpur to Saroli, as well as in the Lamehra range of hills. I am not also aware of its occurrence in the outcrop south-west of Bhera Ghat. Neither of these bands, however, was closely searched.

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B.—PSILOMELANE.

This mineral is present, as has been already mentioned, as fine thread-like veins in the manganiferous hematite. Sometimes a bed of this hematite has developed on it botryoidal concretions, which increase in size towards the surface so as to become large mammillary masses. The *psilomelane* veins follow the contour of the concretions, and increase in number and thickness towards the outcrop, so as to appear as nearly mammillary masses of pure *psilomelane* at the surface.

This kind of change was specially observed to take place in the comparatively thick shaly strata overlying the micaceous-iron-banded quartzite. The development of *psilomelane* in these was found associated with that of milk-white quartz rocks at some places.

In the manganiferous hematite, formed evidently by the local concentration of disseminated *manganese* in the schistose micaceous-hematite, *psilomelane* usually appears as thin veins, parallel to bedding or filling small fissures, &c. Sometimes an outcrop of micaceous-hematite schist, with dip and strike quite distinct, is abruptly overlaid by botryoidal or mammillary masses of pure *psilomelane*. Usually, however, there intervene between the two a mass of variable thickness composed of bits of manganiferous hematite cemented together by a matrix of *psilomelane*, the whole mass looking as if the hematite had been crushed, and the broken fragments subsequently welded together by the manganese-ore. This is the view held by Mr. Mallet. Wherever, however, the apparently crushed mass was dug into, it was found to pass gradually downward, within sometimes not more than 4 or 5 feet from the surface, into strata which showed no signs of crushing at all, and which, in fact, at places, as at Murhasan, were found to dip rather easy. This appearance of "crushing," at or near the surface, may, it appeared to me, be attributed to surface disintegration of the micaceous-hematite previous to the deposition of *psilomelane;* or, as suggested by Dr. King, to the expansive force exerted during the development of *psilomelane;* or in part to both.

Psilomelane co-exists with manganiferous hematite; and the places where the latter has been found in abundance are also the localities where the former occurs in any quantity.

At Murhasan, there occur thinly-stratified quartzites without any interbedded micaceous hematite. They are superposed by massive quartzose beds which are highly ferruginous. There is considerable twisting of the strike, and the rock which crops out has an appearance of being very much crushed. The shivered fragments of quartzite are cemented by *psilomelane*, and at one spot by *pyrolusite* as well.

At Ponri (4 miles west of Sihora) banded quartzose strata without any micaceous hematite, similar to those just mentioned as occurring at Murhasan, considerably twisted, have developed in them, towards the surface *psilomelane* as thin veins, fillings in of fissures, &c. The *psilomelane* does not appear to go down more than 4 or 5 feet from the surface. The quartzite appears to be converted towards the surface partly into limonite and partly into *psilomelane*. The *psilomelane, in situ*, is very much mixed up with the matrix of the quartz-rock, but nodules of it found along the hill slope are nearly free from it. This fact of the nodules of detrital ore being much richer than the ore *in situ*, was observed almost everywhere. Sometimes blocks rich in

aanganese-ore were found along hill slopes, but the search for the ore *in situ* from rhich the blocks may have been derived proved fruitless.

The quartzose strata after an interspace of about a mile re-appear north-east of)arsani, richly impregnated with *psilomelane* and other manganese-ores. They orm a ridge running in the direction of strike for about 2 miles. The manganese nd iron-ores here are very much mixed together. The former predominate in the ill just north-east of Darsani, as also on Kasai (or Kushi) hill. A pit opened on the outh-eastern slope of the former exhibited some 16 feet of the ore, which appears › be mostly *psilomelane*. In the Kushi hill a distinct syncline was observed. This ill will be again noticed in connection with *pyrolusite*. The quartzose strata of onri, Darsani, and Kushi hill probably belong to the Lora group, and have, in all kelihood, come up by an anticlinal flexure.

A large quantity of *psilomelane* in the form of nodules occurs at Gosalpur (Area , Map of Gosalpur). And a little of the mineral in intimate association with *pyrousite* also occurs at this place and elsewhere.

From the mode of occurrence of *psilomelane* it is impossible to form anything ke an estimate of the quantity present. The quantity of pure *psilomelane* cannot e very great, as it is chiefly confined to the surface. Still it is probably greater ıan that of *pyrolusite*. The quantity of manganiferous hematite, with veins and ests of *psilomelane*, must, however, be regarded as practically inexhaustible.

An assay of an average specimen of the manganiferous hematite (from Danwai aine) made by Mr. Mallet, gave the following result (Rec., Vol. XVI, p. 101):—

Ferric oxide	66·33	= Iron 46·43
Manganese (with traces of cobalt)	12·26	
Oxygen	6·83	
Phosphoric acid	·27	
Sulphuric acid	·03	
Sulphur	trace	
Ignited insoluble residue	9·55	
Lime, alumina, water and undetermined	4·76	
	100·03	

The ore would be useful for the manufacture of steel. At present it is used for he manufacture of a kind of a steely iron, known as *kheri*. A brief account of the *kheri* industry will be found in Note A.

A specimen of *psilomelane* analysed by Mr. Mallet yielded 83·20 per cent. of he available peroxide.

II.—PYROLUSITE.

Its distribution is generally co-extensive with that of the Gosalpur quartzites.[1] At places, however, the mineral is present as mere traces. It was found in any quantity at the following localities:—

1. *Gosalpur*—Except in the ground just in front of the dâk bungalow (some o yards to south-east of it), the *pyrolusite* occurs here in and among the Gosalpur quartzites, usually soft, decomposed, and blue-coated at the outcrop. Sometimes he rock is hard, and either white or red in colour, assuming in the latter case the

[1] A band underlying, and probably forming the base of, the Lora group.

appearance of jasper. Wherever such is the case, manganese-ores are wanting. Frequently the rock appears as a conglomerate or breccia, fragments of soft, decomposed (sometimes almost powdery) quartzite being cemented together, as it were, by a matrix of *manganese* or iron-ore. Wherever such a rock crops out, *manganese* or iron-ore is found in some quantity by digging close to it through the soil-cap under which it passes, the nature of the ore being determined by that of the "matrix" at the outcrop.

The quartzites have the general Bijawar strike of the area, *viz.*, N.E.-S.W., The dip is obscure: it was found to be very high (about 80°) pointing S.E., some 150 yards north of the dâk bungalow.

The details of some of the sections as exposed by the pits (see Map of Gosalpur) at this place may not be uninteresting. The great majority of them may be grouped in two lines, 250 to 500 feet apart, running nearly E.—W., roughly parallel to each other.

Commencing with Pit No. XIII, at the western extremity of the southern line of pits, the sections are as follows:—

Pit XIII.

1′5″ Soil with grains and nodules of iron-ore.

6′ Large blocks of hematite, some with fragments of decomposed quartz rock passing below into decomposed quartzites with veins of hematite.

Pit XIV.—One hundred and seventy-five feet east-north-east of last pit. It is an old, large, squarish pit, measuring 23 feet east to west. At its northern end there is an outcrop of the Gosalpur quartzites, either coated blue or having the appearance of a "breccia," such as has been described above. The pit was deepened at two ends to 30 feet at the western, and 12 feet at the eastern end.

1′ Soil with blocks of quartzite.

1′ Grains and nodules of iron-ore, with a few occasional grains of *pyrolusite* and fragments of quartzite.

5′6″ Abundant *psilomelane* in flat, platy masses, with which are associated *pyrolusite* and hematite as grains and nodules.

The shaft at the western end of the pit disclosed below the last-mentioned layer a thickness of—

22′6″ of decomposed, rotten, crumbly, whitish, yellowish, and mottled speckled quartz-rock with veins and nests of *pyrolusite*, passing below into similar decomposed speckled rock, but without these veins and nests. Small pockets of well-crystallised *pyrolusite* were found, however, in the latter at various depths. The speckled appearance is due to the presence of brownish specks, which will be described hereafter.

Pit XIX.— Two hundred and twenty-five feet to east of last—

6″ Soil.

3′6″ Platy, flat and botryoidal masses of *psilomelane*, with some *pyrolusite* (the former predominating largely), and grains and nodules of iron-ore.

4′ Decomposed yellowish and mottled quartz-rock, with veins and nests of *pyrolusite* and *psilomelane*.

Pit XV.—Fifty feet east of last—

1′ Soil.

4′ Nodules and grains of iron-ore, and of *pyrolusite* largely associated with *psilomelane*.

4′6″ Yellowish decomposed quartz-rock with nodules of earthy-looking *pyrolusite* (?).

3′ Yellowish, decomposed, quartz-rock, with veins and nests of *pyrolusite* (?), which disappear towards bottom.

Pit III.—Two hundred feet east-south-east of last—

1′ Soil.

6″ Nodules and grains of iron-ore, with a little *pyrolusite* towards base.

3′ Grains and nodules of iron-ore and of *pyrolusite*, the latter measuring $\frac{1}{8}$″ to 2″ across, and associated with *psilomelane* (but not so largely as in the previous pits).

3′6″ Decomposed quartz-rocks with grains and nodules of *pyrolusite*.

Pit XXVIII.—One hundred feet east of last—

3′ Soil.

2′6″ Nodules and grains of *pyrolusite* and of iron-ore, the former averaging probably less than $\frac{1}{2}$ inch in diameter.

1′ Large blocks of very good *pyrolusite*, somewhat spongy in texture, with cavernous spaces occupied by yellowish, decomposed quartz-rock.

1′2″ Decomposed yellowish and yellowish-white mottled quartz-rock, with veins and nests of *pyrolusite*.

Pit XXXI.—One hundred and ten feet east of last.—This is one of three pits sunk in a large, old, partially filled-up pit, from which *pyrolusite* used to be raised of old by glass-makers.

2′ Soil.

2′8″ Abundant nodules of *pyrolusite*, $\frac{1}{4}$ inch to 6 inches in diameter, mixed up, as usual, with nodules of iron-ore. A little *psilomelane* and *wad* occurs in association with the *pyrolusite*.

4′10″ Fragments of decomposed yellowish, and yellowish-white, mottled quartz-rock, becoming larger and more abundant towards bottom. *Pyrolusite* occurs in the interstices in larger blocks than in the preceding stratum and with cavernous spaces containing the decomposed quartz-rock.

Decomposed quartz-rock with veins and nests of *pyrolusite*.

Pit XLVI.—Seventy-five feet south-east of last—

2′4″ Grains and nodules of iron-ore.

3′10″ Yellowish and brown mottled ferruginous grit, or gritty clay, in large blocks.

6″ Spongy nodules of *pyrolusite* with decomposed quartzite.

Pit XLVII.—Fifty feet south-east of last—

9′ Yellowish and brown ferruginous grit, or gritty clay, without a trace of *pyrolusite*. The rock was found so hard that it had to be blasted.

Pit XXV.—Five hundred feet east-north-east of last, in the Bazar.

3′ Soil.

4′4″ Hard, yellowish loam, with grains of *pyrolusite* and iron-ore.

12′ Nodules and grains of iron-ore, at places compacted into large, hard blocks with abundant oolitic grains (internally black, *pyrolusite* ?), and a few large nodules of hematite and of *pyrolusite*.

Decomposed quartzite with veins and nests of hematite.

Farther east, a section, some 20 feet in thickness, is exposed in an old *baoli*, opposite the police station. The entire depth consists of ferruginous, more or less cellular, gritty clay (Laterite).

The northern line of the more important pits alluded to before may be taken to commence with Pit XX, 225 feet north-west of Pit XIII (the westernmost one of the southern line of pits just described).

4′ Soil with small grains and nodules of *pyrolusite*, averaging ½ inch in length, and big lumps of hematite (some with segregations of *pyrolusite*).

2′8″ Decomposed, crumbly, yellow and white mottled quartzite.

Pit XXXV.—One hundred and seventy-five feet east-north-east of last—

4′ Soil with fragments of quartzite, and grains and nodules of *pyrolusite* and of hematite (a little *pyrolusite* and *psilomelane* being associated with the latter). The nodules, as usual, are generally of a spongy texture.

Pit XXII.—Five hundred and seventy-five feet east of last—

9″ Soil with small grains and nodules of *pyrolusite*.

1′9″ Abundant *pyrolusite* in nodules, and small angular and irregular plates, with fragments of quartzite and grains and nodules of iron-ore.

1′6″ Large blocks of *pyrolusite* with decomposed quartzite.

1′ Blocks of yellow and mottled decomposed quartzite with *pyrolusite*, occupying interstices between them.

Pit XLIII.—Two hundred and fifty feet east of last—

8″ Soil.

5′ Nodules and grains of iron-ore and fragments of quartzite. Towards bottom, large spongy blocks of hematite with decomposed quartzite.

Decomposed quartzite.

Pit XXVI.—Six hundred and twenty-five feet east-north-east of last—

8′ Small grains and nodules of iron-ore with big lumps of hematite of a spongy texture, associated with a few small nodules of *pyrolusite*, the latter being quite subordinate.

2′6″ Decomposed yellow and white quartzite, with veins and nests of hematite and *pyrolusite* (?).

The ground lying to east of this pit is covered by nodular iron-ore compacted into hard rock (Laterite), forming a somewhat high ground. At the foot of this ground, 1,075 feet east-north-east of Pit XXVI, an outcrop of quartzite was met with in Pit XXVII, with veins of hematite. In a well, a few yards from this pit, reddish and white mottled quartzose shales were met with at a depth of 4 feet from the surface.

North, south and east of the area enclosed by the two lines of pits described above, the ground is covered by nodular iron-ore usually compacted into hard rock. Some pits were sunk into it. Several in the northern portion of the ground, disclosed, at a depth of about 9 feet or so, decomposed quartzites similar to the rocks invariably found at the bottom of the pits described above when deep enough.

In the ground west and north-west of the dák bungalow, the rock found below the nodular iron-ore (which is of small thickness) is a ferruginous, red and yellow and brown grit or gritty clay, similar to that found in Pit XLVII. About 50 yards

st and south-east of the dâk bungalow, a few fragments of slaty-looking micaceous hematite were found mixed up with the nodular iron-ore. A trench varying depth from 6 to 12 feet, disclosed the former rock *in situ*, but to all appearance ery much crushed, fragments of it being held together by a ferrugino-*manganirous* cement. This rock passes into a lateritic-looking rock containing iron-e and *manganese*-ore (*pyrolusite* intimately associated with a little *psilomelane* id iron-ore) in which not a trace of the micaceous hematite was observable. A rge quantity of *manganese*-ore was raised from this trench. That its occurrence, owever, is exceptional, is evidenced by the following section disclosed by a pit KVI) in front of the bungalow, not many yards from the trench just mentioned :—

5′ Nodular iron-ore.
8′ Blocks of hematite with bits of micaceous iron-ore.
10′ Soft, earthy, micaceous hematite.
4′ Compact and very hard red hematite, so hard that it had to be blasted.

The *pyrolusite* area of Gosalpur is divisible into five portions (see Map 1) :—

(*a*) Stretching east-west from Pit XLVI to Pit XV, and north-south from a point few yards north of Pit XXII to a point between Pits III and XV. Here the *pyrousite* is the predominating mineral, *psilomelane* and iron-ores being quite suborinate to it. The greatest thickness of the ore-bearing stratum (leaving out of conideration the quartzites with veins and nests of *pyrolusite* as unworkable with profit) 7 feet 6 inches (Pit XXXI), and the least 1 foot (Pit XXXIII, not described above). 'he former thickness is, however, somewhat exceptional, and the mean should probab- be taken at not more than 3 feet 6 inches. Towards the surface, the *pyrolusite* odules are mixed up with those of iron-ore, and towards bottom, they contain a good ortion of the matrix of the quartzite, in which it occurs as veins and nests deeper own. The quartzite is, however, much decomposed, loose and crumbly, and is, erefore, easily separable. Making allowance for it and for the grains and nodules f iron-ore, it would not be safe to take the thickness of pure *pyrolusite* (associated ith a little, but very little, *psilomelane*) at more than 1 foot 6 inches.

The greatest length of the principal *pyrolusite* area is 525 feet, and the greatest readth 338 feet. The area is about 157,500 square feet. There are several small outrops of the Gosalpur quartzites within this area; and the *manganese*-ore is present in hem as mere traces. The area covered by them cannot be less than 20,000 square eet. Applying this correction, the estimated *pyrolusite* area would be reduced to 37,500 square feet. Thus the quantity of *pyrolusite* present here would occupy 37,500 $\times \frac{3}{2}$ cubic feet = 206,250 cubic feet.

The specific gravity of an average specimen of the *pyrolusite* from this area, letermined in the laboratory of the Geological Survey, was found to be 4·7. Thus he weight of the quantity available here would amount to 27,000 tons (about).

It should be observed that a portion of this amount (by no means inconsiderble) has been taken away from the old pit (the richest portion of the ground etween Pits XXX and XXXI) by glass-makers and others; and that a portion has een raised from the trial excavations successively made by Mr. McMinn, Mr. Jones nd myself, and is lying at the place.

The cost of raising the ore is trifling, as it occurs at a very low depth from the surface, and can be dug out with facility. It should, however, be observed, that

a large portion of the ore occurs in small grains, coated red by oxide of iron; and the sifting of these from similar grains of iron-ore needs time, care, and experience. The proportion of larger blocks and nodules of *pyrolusite*, measuring from nearly a foot to half an inch in length to smaller grains was found in Pit XXVIII to be nearly 1 to 3. So that the former kind of ore in the area under consideration does not probably amount to more than 9,000 tons. Of this amount, that already removed may be put down at about 500 tons, if not more. So that the quantity still available of the larger nodules of the ore (above half an inch in length) probably does not exceed 8,500 tons. This estimate is no doubt very vague, and it is given here, as it may give a better idea of the quantity of the ore available than mere guesses.

(*b*) In this area, the *psilomelane* either predominates over the *pyrolusite*, or the two minerals are present in about equal proportion. It stretches south-westward from Pit XV. Its length may be taken at about 470 feet, and breadth at about 80 feet. Thus the area may be estimated at 37,600 square feet. Making allowance for an outcrop of the Gosalpur quartzites, in which the *manganese*-ores occur as mere traces, or do not occur at all, this estimate would be reduced to probably 24,000 square feet. The greatest thickness of the ore-bearing stratum is 8 feet 6 inches (Pit XV), and the least 3 feet 6 inches (Pit XIX). A mean of 5 feet may, I think, be safely taken. The ore, however, is mixed up with grains and nodules of iron-ore. Making allowance for these, the manganese-ore (*pyrolusite* and *psilomelane*) may be taken to occupy a thickness of $2\frac{1}{2}$ feet. Thus the volume of the manganese-ore would amount to $24{,}000 \times \frac{5}{2} = 60{,}000$ cubic feet.

Of this volume not less than half, probably more, say, about three fifths, would be occupied by *psilomelane*. The cubic contents of the *pyrolusite* would thus be about 24,000 cubic feet. Taking its specific gravity at 4·7, it would amount to 3,000 tons (about).

If allowance be made for small grains of *pyrolusite*, this quantity would be still further reduced.

(*c*) (c^1) Two detached areas, one situated north of (*b*), and the other in the village, are included in these divisions. Here the *pyrolusite* is present as nodules or small grains, quite subordinate to similar nodules and grains of iron-ore (hematite, &c). From pits XXV and XXVI (inside the village) only a few nodules of *pyrolusite* of any size were obtained, it being present chiefly as oolitic grains, too small probably to be profitably sifted from similar ones of oxide of iron (both being coated red outside), and worked for purposes for which pure, or tolerably pure, *pyrolusite* is required. It is impossible to form even such a vague estimate of the quantity of *pyrolusite* present in these two areas as has been given for (*a*) and (*b*). It would probably not amount to more than what has been estimated to occur in (*b*).

(*d*) In front of the dâk bungalow, by the road leading from it to the Mirzapur road. Here the *pyrolusite* occurs in "lateritised" micaceous hematite. The iron and manganese-ores are greatly mixed up (the former appearing to predominate). However, a large quantity of blocks and nodules of *pyrolusite* was raised from the trench mentioned before. The area covers about 40,000 square feet. The thickness of the *pyrolusite* may be taken at a fourth of the entire thickness, which is over 12 feet. Thus the cubic contents of *pyrolusite* here would amount to about 120,000

cubic feet. Taking specific gravity at 4·7, the quantity would be about 15,000 tons. The *pyrolusite* here is invariably and intimately associated with a little *psilomelane* and a little iron-ore. The whole of the ore, however, occurs in large blocks and nodules.

Thus the total quantity of *pyrolusite* occurring at Gosalpur may be roughly estimated at about 50,000 tons. It must be remembered, however, that it is almost invariably associated with a little *psilomelane*, and that a good portion of this quantity consists of very small grains, mostly coated red outside by oxide of iron.

2. *Keolari* (*a deserted village*).—There is an outcrop here of what appeared to me the Gosalpur quartzite, a mile nearly due south of the dâk bungalow at Gosalpur. The quartzite runs parallel to a band of "lateritised" micaceous hematite, similar to that occurring in front of the Gosalpur bungalow, but without any *pyrolusite* as far as ascertained by a trench dug close to the road leading from the Mirzapur road to Khumarea. The quartzites are surrounded, as at Gosalpur, by nodular iron-ore compacted into large, hard blocks at places. Their outcrop is about 600 yards long and 150 yards broad. At the north-eastern edge of it, where they pass under alluvium, some pits were sunk, which disclosed a large quantity of manganese ores. A good portion of these is *wad*; very little *pyrolusite* was found.

3. *Murhasan.*—This place is situated at the south-eastern extremity of the eastern portion of the Lora Syncline.[1] At the northern edge of a hillock just west of the village, apparently much crushed quartzites crop out with veins and nests of *pyrolusite.* A pit here exposed a thickness of 3 feet of large nodules of *pyrolusite* of a somewhat spongy texture, passing below into quartzose rock with a network of veins of *manganese-ore* as in the Gosalpur pits. The *pyrolusite* is associated with *psilomelane;* and the rest of the hillock is constituted of contorted Lora strata in which the latter mineral is alone found. The *pyrolusite* area here is probably not more than 625 square feet in extent. Much of the ore, however, is mixed up with the quartzite in which it occurs. The quantity of *pyrolusite* here would not probably exceed 200 tons.

Proceeding north-eastward from Gosalpur along the eastern side of the Lora syncline, the next notable occurrence of *pyrolusite* is at 4.—*Pahrewa,* a mile and a half south of Sihora. The mode of occurrence of the ore here is somewhat similar to that at Murhasan. It was found on a conical hillock just south of the village (which is very nearly deserted) to the left of the Mirzapur road. A pit on the western slope of this hillock disclosed 7 feet of decomposed quartzites, with considerable nests and thick veins of *pyrolusite* (associated with *psilomelane*). A trench a few yards north-east of the pit, however, at the top of the hillock, exposed apparently crushed quartzose rocks, micaceous hematite, and manganiferous hematite with veins of *psilomelane.*

5. *Khatola* (*Kuthola on map*).—The *pyrolusite* here occurs in two hillocks formed of the Gosalpur quartzites, close to the railway station. The quartzites are worked for railway ballast, and a portion of the *pyrolusite* has gone with it. I pointed out the ore to the contractor working the ballast pits, and verbally told him

[1] The syncline formed by the Lora group, well seen just west of Gosalpur, and more or less distinctly traceable south-eastward to Murhasan and Kailwas, and in the north-western direction to the Lora range proper.

not to carry it off with the ballast. At one spot, in the smaller of the two hills west of the Saroli road, the *pyrolusite* was found in massive, somewhat cellular, blocks at the surface; digging down, however, it was found to get mixed up with the quartzite. The ore is scattered over a good area. But there is probably no considerable quantity of it, as it is confined to the surface, or occurs chiefly as mere traces.

6. *Bhatadon* (*a mile south east of Khatola, on the south side of the Hirun*).—Here the ores occur on a small hillock partly composed of the Gosalpur quartzite and partly of lateritic rock. Exceptionally good *pyrolusite* was found at one spot, free from quartzite-matrix. Digging disclosed a thickness of 8 feet of the ore, but mixed up towards the bottom with the quartzite as at Khatola. A few hundred tons of *pyrolusite* may be expected from here.

7. *Hargar* (*2½ miles east of Khatola*).—There is a strong outcrop of the Gosalpur quartzites here. The *pyrolusite* was found to occur as mere traces. It was, however, found in some quantity at the south-western edge of a hill situated between Hargar and Daroli. It occurs in association with iron-ores, and the quantity is probably small.

Traces of *pyrolusite* were found at several spots at Danwai (Dunwie) in the lower quartzite hills running parallel to the Lora range. It was found, however, in some considerable quantity at:—

8. *Mungeli* (*Mungeilee*), *close to the road leading from Sihora to Umaria* (*Oomria*).—Five pits north of the road, at the foot of the hill just west of the village, exhibited an average thickness of 2 feet of *pyrolusite*. At a depth of 4 or 5 feet from the surface it is mixed up with the matrix of the rock which is thin bedded quartzite. Deeper down the rock occurs without the ore, at least visibly. A pit south of the road exhibited under 4 feet of alluvium, 5 feet of quartzose-rock with *pyrolusite*.

Beyond Mungeli, traces of *pyrolusite* were observed at Deori (Deoree), close by the Umaria road in an insignificant outcrop of quartzites.

On the western side of the Lora syncline, the following localities may be noted commencing from the northern portion of the ground:—

9. *Chhapra* (*Chhota*), *5 miles north-east of Sihora*.—In one of several pits sunk in a hillock a quarter of a mile south of the village, nodules of *pyrolusite* largely associated with *psilomelane* and *wad* and mixed up with blocks and fragments of quartzite, with or without veins and nests of the manganese-ores, were found to a depth of 10 feet from the surface. The quantity of *pyrolusite* here must be very small; and the nodules of it are never quite free from the quartzose rock.

10. *Sihora*.—At and about this place *pyrolusite* is present in fairly large quantity.

Just north of the encamping ground, a ridge of quartzose rocks runs along the strike north-eastward for a little over 2 miles. At the north-eastern extremity of this ridge traces of *pyrolusite* were found, but the pits dug here did not show any quantity of it. Further search here may prove more successful.

The ridge at places is formed of beds of hematite with interbedded laminated red jasper, passing below (vertically) and laterally (along strike) into quartzose rocks with impregnations of iron ore.

The ridge (which from the villages through which it runs may be called the

Mansukra-Silondi ridge) is scarped on the northern side, the strata dipping south-east. On this (the northern side) a pit exhibited shaly-quartzose strata underlying similar strata impregnated with iron-ore, these last passing under beds of hematite with interbedded jasper. The dip is about 40° south-east. The hematite, at the surface, is largely associated with manganese-ore, which I believe is *pyrolusite*. These mixed manganese-iron-ores are very plentiful in the portion of the ridge (1 mile in length) included within the limits of Mansukra, from the Mirzapur road to the streamlet forming the eastern boundary of that village. At spots the manganese predominates over the iron-ore, and sometimes, but rarely, the former is almost exclusively present. When the latter is the case, the *pyrolusite* is usually of small thickness (2 feet or less) and of small extent, passing vertically below and on all sides into iron-manganese ores, or quartzose rocks containing traces of these.

At one place, about 900 feet west of the boundary line between Mansukra and Silondi, the ore was found to be almost free from iron-ores and quartzose-matrix, and of exceptional thickness. Here almost a solid mass of good manganese-ore (*pyrolusite* intimately associated with a little hematite, and a little, but very little *psilomelane*) goes down to a depth of 11 feet in one of the pits. At this depth hematite with a trace of manganese-ore occurs. From the pits sunk here, the *pyrolusite* was found to cover an area of about 10,000 square feet. Taking its average thickness at 7 feet, there is present here some 70,000 cubic feet of manganese ore. Taking the specific gravity at 4·7, the quantity would amount to about 9,000 tons. From the entire hill some 12 or 13 thousand tons of the *pyrolusite* may be expected. From an assay made by Mr. E. J. Jones, of the Geological Survey, it was found to contain 81·24 per cent. of the available peroxide of manganese.

Inside the town of Sihora, nearly at its northern extremity, on a low ridge formed of cherty-looking quartzites, curiously intermingled with lateritic rock, rather good *pyrolusite* was found at one place. Traces of the ore were also found just west of the town by the road leading from it to Majhauli in an outcrop of the Gosalpur quartzites.

In the compound of the local court-house, where there is an outcrop of the Gosalpur quartzites, a pit showed, below 1 foot 8 inches of soil, a thickness of 12 feet of decomposed quartzose-rocks with nodules of manganese-ore, which appeared to be chiefly *wad*. The ore was mostly raised as a black powdery mass. Another pit, a little to the south, exhibited some 7 feet of quartzites, with veins and nests of *pyrolusite* (?).

11. Naigain.—South of Sihora, the quartzites are lost under alluvium. They re-appear at Naigain on the Hirun river, 2 miles north of Gosalpur. In one of the pits opened here, *pyrolusite* occurs as nodules in decomposed, yellowish quartzites down to a depth of 4 or 5 feet from surface. The quartzite at the surface contains veins and nests of the ore. But I do not expect there is any considerable quantity of it.

Proceeding southward traces of *pyrolusite* were found in the quartzites near Chandnota by the Hirun. The ore occurs in some quantity at,—

12. Dharampur.—A little over a mile west-north-west of this village, at the foot of a hill locally known as Changeli, there is an outcrop of apparently the Gosalpur quartzites, which at one place has the appearance of a breccia, consisting of frag-

ments of quartzite cemented by a matrix of *pyrolusite*. A trench dug close to it showed a good thickness of the ore, but seldom free from quartzite. The thickness was found to be 10 feet in one of the pits. The extent is some 30,000 square feet, if not more. Taking the average thickness at 6 feet, some 180,000 cubic feet of the ore may be expected from here. The ore is, however, as has just been observed, seldom entirely free from the quartzite. Making allowance for it, the quantity of dressed ore may be estimated at about 13,000 tons.

13. Dhangaon.—Nearly at the top of a low hill covered by thick scrub jungle, a mile north-east of this village, and close to the boundary line between it and Tala, an outcrop of quartzites similar to the one just mentioned led me to expect the ore; and it was found, though in thickness and extent it appeared to be poorer than the Changeli find.

14. Chindamani (Cheendamanee).—*Pyrolusite* occurs here, as at the last two places, in an outcrop of apparently the Gosalpur quartzites, about a quarter of a mile north-east of the village.

Traces of *pyrolusite* were also found at Kailwas (a mile north of Chindamani), one-third of a mile north of the village, in quartzites.

15. Nurgaon (nearly 4 miles east-north-east of Panagar).—A little over a quarter of a mile east of this village, in a *nala* at the foot of a ridge of Gosalpur quartzites, a small pocket-like deposit of *pyrolusite* was found amongst these. On the ridge, however, the quartzites were found impregnated with iron-ore alone.

16. Pararia (Purrurea).—A quarter of a mile east of this village (2 miles south-east of Panagar), there is a ridge of quartzites which have the appearance of being greatly crushed. At one place, at the south-eastern extremity of this ridge, and at its foot, a crust of well-crystallised *pyrolusite* was found on the surface of blackish quartzites. A pit here showed these rocks to be more or less impregnated with the ore. On the ridge, a little to the north-east of this pit, it also occurs, but with considerable admixture of the quartzite.

It is highly probable that the quartzite bands which stretch north-eastward from Nurgaon, and east-north-east from Pararia, if searched more closely than I was able to do, would yield some *pyrolusite*; but, from what I saw, I doubt if it is likely to be of good quality.

17. Kushi (Kasai) hill, 3 miles north-west of Sihora.—Manganese-ores are very plentiful in this hill. They appear, however, to be chiefly *psilomelane*.

At the south-eastern extremity of this hill, at its top, I observed some massive quartzites identical in appearance with the Gosalpur quartzites, and forming a syncline. Pits opened here exhibited some *pyrolusite* as nests in the quartzites.

Outside the Lora group, and nearer the base of the Bijawars of this area, traces of *pyrolusite* were found in the Majhauli-Bhitri group at the following places[1] :—

(A). CHHAPRÁ (*Bara*), 3 miles south of Sleemanabad.—On the southern slope of a hill, half a mile east of this village, at the boundary between it and Salaiá, I encountered a block of quartzose rock with nests of *pyrolusite*. The hill is covered by cherty rocks in boulder-like masses. Some pits were dug here, but no manganese-ore was found in any of these.

[1] For the places, see Map accompanying Mr. Mallet's paper on the Iron-ores of the Jabalpur district (Rec. Vol. XVI. Part 2).

(B). HARDUA KHURD (Hurdooa khoord), 12 miles west-south-west of the last ›lace.—A mile north of this village at the south-western end of a ridge of cherty-ooking reddish quartzites, traces of *pyrolusite* were observed.

(C). MURAITH (Mooreith), 7 miles north-west of Gosalpur.—Here traces of *›yrolusite* were found in some cherts occurring among chert-banded limestone

With regard to the Bijawar ground south-west of Jabalpur, I had time only to ›ay a hurried visit to Gangai, 4 miles south of Bhera Ghat. The Lora group occurs ıere, as has been mentioned by Mr. Hacket in his manuscript report. He notes he presence of quartz-rocks in the western portion of a hill near Dharampur, 3 niles south-west of Bhera Ghat. These rocks may be the representatives of the Gosalpur quartzites in this area. They certainly appear to run parallel to the Lora iron-ore-band, and may, I think, yield some *pyrolusite*.

A carefully selected average sample of the *pyrolusite* from Gosalpur yielded on ınalysis (Mallet "Man. of the Geol. of India," pt. IV, p. 58):—

Manganese	54·66
Oxygen	31·16
Iron Sesquioxide (with trace of alumina)	4·53
Baryta	3·56
Phosphoric acid	·28
Insoluble in hydrochloric acid	2·74
Combined water	2·41
Hygroscopic water	·28
	99·61

NOTE (A).

Notes on the Iron industry of the Lora hill area.

Nearly every village in the vicinity of the Lora range worked the manganiferous ıematite ore at some time or other, as the slag mounds testify. South of the Hirun there vere mines at Hirdenagar and Gosalpur. But north of the river, nearly all the furnaces ppear to have been supplied by the Danwai mines situated at the boundary between Danwai and Gogra.

Last February, I saw four furnaces at work, two at Karaia and two at Hatwai—two mall villages near Kaleri, about 9 miles north-east of Sihora. These four furnaces had een working since November. Two more furnaces were about to start work at Gogra hen I visited that place (about the end of February).

The furnace, as usual, is of a most primitive type. It is 4 feet 6 inches in height om the hearth to the throat. The width is 1 foot 6 inches at the hearth, and 7 inches at ıe throat. The furnace is built of mud, with which some straw is mixed. The making-p of the furnace costs a rupee or so.

The bellows which supply the blast are about a foot and a half high when stretched. hey are made up of goat's skins obtained from Jabalpur at a cost of R4 per pair; ıe making-up costs a rupee. A pair of bellows lasts one full season (November to lay).

The entire cost of the furnace and bellows and other requisites amount probably to ɔt more than R7.

The blast is supplied through a pair of clay tuyers, which are renewed every day.

The manganiferous hematite (which is the ore used) is procured from the Danwai ines. The ore has to travel 5 miles for the furnaces at Karaia, and 7 for those at .atwai. It is carried on pack buffaloes to Karaia at a rate of 2 annas 9 pies for one

day's charge required for each furnace. This includes the cost of digging out a dressing the ore (*i.e.*, breaking up the bigger lumps into small bits and roughly se ing it from the rock matrix which is quartzite). The rate at Gogra, which is only from the mines, is 2 annas per charge.

The fuel used is charcoal. The price paid for it is 8 annas for one day's sumption. This includes carriage. The quantity of charcoal consumed by a fu in one day averages 4 maunds, so that it costs 2 annas per maund. This price a to be abnormally low. I was told that it would take 12 men to work regularl month to prepare charcoal required for a month by one furnace; that is to say, the neration for these 12 men would be R15 per month, or R1-4 per head. Ther doubt that all the 12 men do not work steadily and systematically; and it is probab 8 men would suffice if they work properly. Even then, however, the wage of a la per day would not be more than 1 anna, which is below the normal rate. The ch is procured at this low price by making advances to labourers during the rains.

The furnace is worked for 12 hours, from about 8 in the morning to late in th ing. Two men are required to work it, one at the bellows and the other to ore and fuel and let out the slag. Their wages vary from 2 to 3 annas each per d

The furnace is first filled up with charcoal. When it gets well heated, ore down through a hole at the top about 7 inches square, one small basketful at weighing from 5 to 7 seers. Some 25 to 30 such basketsful (or 3½ to 4½ maunds) are consumed by a furnace in one day.

The produce of the furnace is a steely iron, known as *kheri*,[1] which is used for t implements of various kinds such as hatchet-heads, ploughshares, &c. As sugge Mr. Mallet, there can be no doubt that the quality of the iron is due to the prese manganese in the ore.

The spongy mass of *kheri* which comes out of the furnace is partially mixed w slags. When cooled, it is beaten down with a heavy hammer, and broken into blocks and fragments, the slags separating out in the process. The daily outtu furnace averages 24 seers of *cleaned kheri*.

The selling price varies. At the furnace it averages R10 per *gond* (= 24 p or 3 maunds and 24 seers), or about 14 seers per rupee. At Sihora the price, acco to my information, was 8 seers per rupee.

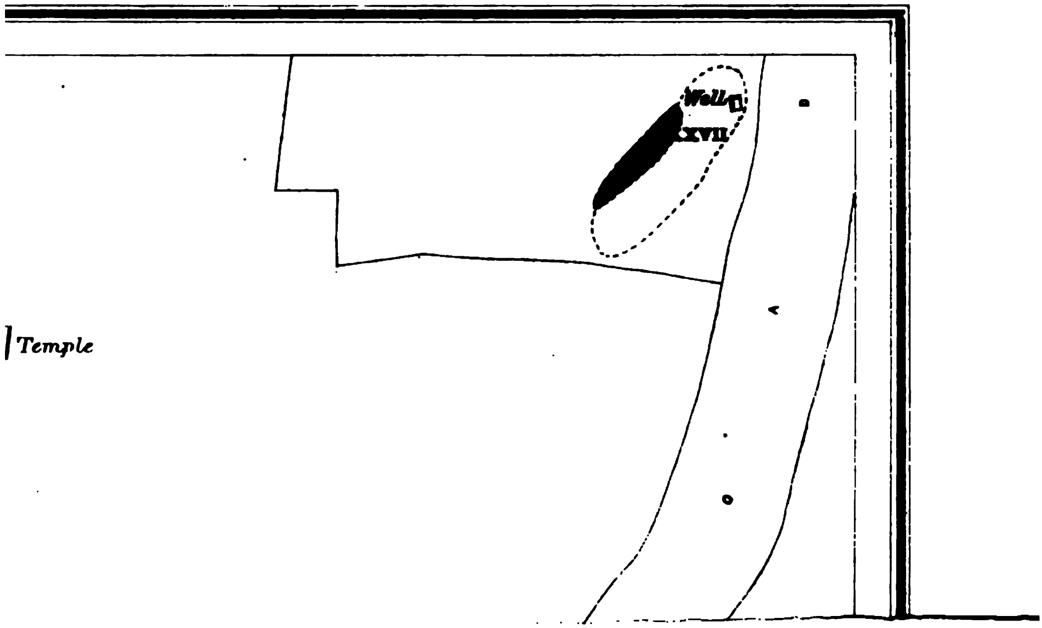
The working expenses of a furnace per month may be estimated as follows:—

	R	a.
Digging, dressing and carriage of ore at 2 annas per day (the Gogra rate)	3	12
Charcoal at 8 annas per day	15	0
Two bellowsmen (6 annas per day)	11	4
Duty on wood burned for charcoal	4	0
Royalty on ores	1	6
On account of bellows, &c.	1	0
Total	36	6

The monthly outturn averages 30 × 24 seers = 18 maunds. At R10 per go 3⅗ maunds, the value of the outturn would be about R51-6. This leaves a fair ma for profit.

If the Umaria coal be found suitable, there is very good prospect for a steel m factory on a large scale in the Lora hill area; and Khatola, where there is a ra station, appears to me to be best suited for the purpose. There is very rich manga ous iron-ore close by (see p. 75); and the Hirun, probably the largest river i northern portion of the Jabalpur district, flows past it.

[1] According to Mr. McMinn (*Central Indian News*, September, 1886), *Kheri* contains "8 cent. of steel worth £45 per ton. It costs now in Jabalpur under £6 per ton."


Well
XVII
Temple

NOTE (B).

The following statistics compiled from Phillips' "Treatise on Ore Deposit" and R. Hunt's "British Mining," may be found useful in forming an estimate of the value of the Jabalpur ores. The Manganese ores include *pyrolusite, manganite, psilomelane,* &c.:—

YEAR.	Quantity of manganese-ores.	Value.
I.—THE UNITED KINGDOM—	Tons.	£
1. Production of the mines in Cornwall, Devonshire, &c.		
1880	2,839	5,601
1881	2,884	6,441
1882	1,548	3,907
2. Imports.		
1880	16,085	67,070
1881	18,748	71,140
1882	29,760	102,267
II.—FRANCE, 1880	9,652	21,309
III.—THE GERMAN EMPIRE, 1881	13,642	23,534
IV.—ITALY, 1880.	6,505	8,575
V.—SPAIN, 1882	5,668	9,115
VI.—THE UNITED STATES, 1882.	3,500	10,500

"The Carboniferous Glacial Period," *by* Oberbergrath Prof. DR. W. WAAGEN.[1] *Translated by* R. BRUCE FOOTE, F.G.S., *Superintendent, Geological Survey of India.* (With one plate.)

Since the time when Agassiz and others entered upon a close study of glaciers, and it became practicable to recognize deposits formed by ice, even where the forming agency, the ice itself, had long disappeared, perfectly new vistas have opened to geological enquiry, and it has become possible to look back into the climatic conditions of periods which had long preceded historical tradition, and which till then had been regarded as separated by a great gulf from the present development of things. Studies in this direction, however, extended in the first place only to the glacial formations of the quarternary period, partly because the ice-formed deposits

[1] Jahrbuch der K. K. Geol. Reichsanstalt, 1887, 37, Band. 2, Heft. (W. Waagen).

belonging to this period are generally rather superficial in position, cover a comparatively large area, and play thus a more or less important part in the geological composition of many regions; partly also because, for obvious reasons, organic remains are pretty generally absent from glacial formations, and thus the age of such formations as do not belong to the quarternary period is generally extremely difficult to determine.

In spite of this, many voices have already been raised of those who believed they could demonstrate the action of ice in formations older than the quarternary; and there is hardly one of the greater epochs later than the Cambrian in which such formations have not been indicated: indeed, James Croll held that he could prove that each of the greater epochs in the history of the earth must consist of a series of glacial and interglacial periods. In this he deals very liberally with millions of years.

These voices have, however, hitherto died away with rather slight notice, because the whole body of geological facts would not fit in kindly with the theory, and because the facts, and specially those observed in the British islands, appeared on the one hand always as local phenomena only, while on the other hand, an unquestionably glacial character of these formations could not be absolutely proved. As time went on facts increased and proofs accumulated : and to-day it is hardly feasible any longer to wrap oneself in dissentient silence in opposition to the question whether glacial appearances are not traceable in prequarternary times ; for the fact of the existence of glacial deposits is pretty generally admitted, although one could not begin to do much in general with this fact, a close determination of the age of these glacial formations being subject to very special difficulties.

It is one of the incontestably great merits of the Geological Survey of India to have advanced this "Glacial" question into the foreground, and to have published numerous facts tending towards its solution. The first case which was established by these studies, and which was one of great weight, was the fact that it appeared thus to be proven that the glacial beds in formations older than the quarternary are not merely local phenomena such as are found only in certain localities in England, but are really widespread and extending over great parts of the earth.

The oldest observations of the kind concerned India; where, in the year 1856, the so-called Talchir conglomerates were discovered, which were at the time pronounced by W. T. Blanford to be glacial. The definitive proofs of this were, however, only obtained in 1872 by Thomas Oldham and Fedden, who jointly excavated in the valley of the Godavari numerous scratched blocks of these beds, and also found the underlying formation, a hard Vindhyan limestone, to be scored with innumerable deep parallel scratches. A large granite block then found is exhibited in the Indian Museum in Calcutta, and forbids any doubt as to its having been tooled by ice.[1]

Another region in which conglomerates of peculiar character had long been known is South Africa. This formation was for a long while held to be of volcanic origin, till at last Sutherland[2] recognized the glacial origin of these block deposits

[1] Mem. Geol. Surv. Ind., Vol. IX, Part 2, p. 30. (Mr. Fedden made the original find. W. K.—*Ed.*)

[2] Quart. Journ. Geol. Soc. Lond., Vol. XXVI, p. 514.

also. Our countryman Griesbach, who knew these deposits from personal inspection in South Africa, was, when he came to India, surprised at the similarity which the Indian Talchir conglomerates show to the South African conglomerates, and did not hesitate to bring the two formations into correlation.

A third region in which glacial deposits in older formations were indicated was Australia. Before all others, it was the so-called Bacchus-marsh sandstone that was recognized as glacial, while the Hawksbury beds also appeared to have come into existence under glacial influences.

In all these three regions the glacial deposits appear in connection with coal seams, or sandstones containing a rich flora. This flora was by the majority of, and the best, palæophytologists regarded as Mesozoic; but the stratigraphical relations in India, and yet more especially in Australia, distinctly demanded that these formations should be reckoned in the Palæozoic rock series.

An irresolvable contradiction was thus created, which called forth a division of minds. Endless controversies were held in favour of one or other view: and the importance of the occurrence of glacial formations in these beds receded into the back ground, just because the exact age of the whole series of beds could not be determined with certainty. I will now endeavour to give a picture of the relative conditions for German readers, but in so doing cannot avoid repeating much that has already been variously discussed in German periodicals.

I.—INDIA.

The fundamental studies of these formations were published in 1856 by W. T. Blanford; and later on the whole series of beds received from H. B. Medlicott the name of "The Gondwana System."

Comprehensive data on this subject were given by W. T. Blanford in the *Manual of the Geology of India*, and more lately in his Address to the British Association at Montreal. His brother, H. F. Blanford, also gave a very good review of the subject, as then known, in his essay "*On the* Age *and* Correlations *of the* Plant-bearing Series *of* India, *and the former* Existence *of an* Indo-oceanic Continent" (Quart. Jour. Geol. Soc. London, Vol. XXXI, p. 519, 1875). The organic remains were worked out by Feistmantel.

It is difficult to treat the subject afresh since it has been so largely and so well written on. In particular it appears to me hardly possible to excel, or even to attain to, the masterly representation of the conditions given by W. T. Blanford in his Montreal Address: it will therefore be the wisest plan to let the first founder and zealous promoter of the whole question also speak on it in this place. I shall content myself therefore by giving here (in translation) the respective passages in Blanford's Address, and only making such additions to it as appear desirable for the benefit of German readers.

"*Gondwana System of India.*—In the peninsula of India there is a remarkable deficiency of marine formations. Except in the neighbourhood of the coast or of the Indus Valley there is, with one exception (some cretaceous rocks in the Nerbudda Valley), not a single marine deposit known south of the great Gangetic plain. But in Bengal and Central India, over extensive tracts of country, a great sequence of fresh-water beds, probably of fluviatile origin, is found, to which the name of

Gondwana system has been applied. The uppermost beds of this system, in Cutch to the westward, and near the mouth of the Godavari to the eastward, are interstratified with marine beds containing fossils of the highest Jurassic (Portlandian and Tithonian) types.[1]

"The Gondwana system is a true system in the sense that all the series comprised are closely connected with each other by both biological and physical characters, but it represents in all probability a much longer period of geological time than do any of the typical European systems. The highest members, as already stated, are interstratified with marine beds containing uppermost Jurassic fossils. The age of the lowest members is less definitely determined, and has been by different writers classed in various series from middle carboniferous to middle Jurassic. The Gondwana beds from top to bottom are of unusual interest on account of the extraordinary conflict of palæontological evidence that they present.

"The subdivisions of the Gondwana system are numerous, and in the upper portions especially the series and stages are different in almost every tract where the rocks are found. The following are the sub-divisions of most importance on account of their fauna and flora, or of their geological relations :—

Upper Gondwana ...	Cutch and Jabalpur.	
	Kota Maleri.	
	Rájmahál.	
Lower Gondwana ...	Panchet.	
	Damuda ...	Ranigunj and Kámthi.
		Barákár.
	Karharbári.	
	Tálchir.	

"The upper Gondwanas, where best developed, attain a thickness of 11,000 feet and the lower of 13,000 feet.

"The Talchir and Barakar sub-divisions are far more generally present than any of the others.

"*Tálchir.*—The Tálchir beds consist of fine silty shales and fine soft sandstone. Very few fossils have been found in them, and these few recur almost without exception in the Karharbári stage. The Talchirs are principally remarkable for the frequent occurrence of large boulders, chiefly of metamorphic rocks. These boulders are sometimes of great size, 6 feet or more across, 3 to 4 feet being a common diameter; all are rounded, and they are generally embedded in fine silt."

These boulder beds are very widely distributed in Bengal and Central India, and boulders whose surfaces are marked with numerous parallel scratches are by no means uncommon. They form generally the base of the whole coal and plant-bearing series, and rest very often unconformably on older rocks. It has already been mentioned that when the basement is freshly exposed, the surface is scored with distinct parallel striæ. The thickness is often very great, but naturally changes within short distances. The glacial origin of these boulder deposits is clear beyond all cavil.

Griesbach[2] has given a very instructive chromo-lithographed sketch of such

[1] This and the following quoted passages are all from Mr. Blanford's address as President of the Geological Section of the British Association, at Montreal, 1884: also published in Records, G. S. I., XVIII, p. 32 *et. seq.*—W. K.

[2] Mem. Geol. Surv. Ind., 1880, Vol. XV, pt. 2, pl. 2.

a bed, which shows most convincingly the irregular distribution of the boulders in the fine greyish-green sandy clay. The soft sandstone and shales occur generally only above the boulder clay. A few plant remains occur in the shales, and from among them Feistmantel determined the following species :—

Schizoneura, sp.
Gangamopteris cyclopteroides, Fstm.
,, angustifolia, McCoy.
Glossopteris, sp.
Næggerathiopsis hislopi, Bunb., sp.

Of these *Gangamopteris cyclopteroides* is the predominant form, and *G. angustifolia* is identical with a form that was originally described from the Bacchus-marsh sandstone. This Australian formation also shows similar characters.

"*Karharbári.*—The Karharbári beds are found in but few localities." They stand in the closest relation to the Tálchir beds, and can hardly be regarded as a separate division. Here and there they contain coal-seams, and are then often rather rich in plant remains.

Up to the present Feistmantel has described the following species from these beds :—

Schizoneura cf. meriani, Schimp.
Vertebraria indica, Royle.
Neuropteris valida, Fstm.
Gangamopteris cyclopteroides. Fstm. in many varieties.
,, buriadica, Fstm.
,, major, Fstm.
,, angustifolia, McCoy.
Glossopteris communis, Fstm.
,, decipiens, Fstm.
Sagenopteris stolicskana, Fstm.
Glossozamites stolicskanus, Fstm.
Næggerathiopsis hislopi, Bunb., sp.
Euryphyllum whittianum, Fstm.
Voltzia heterophylla, Brogn.
Albertia, sp.
Samoropsis cf. parvula, Heer.
Carpolithes milleri, Fstm.

"The most abundant form is a *Gangamopteris*. The *Voltzia* (*V. heterophylla*) is a characteristic Lower Triassic (Bunter) form in Europe. The *Neuropteris* and *Albertia* are also nearly related to the Lower Triassic forms. The species of *Gangamopteris*, *Glossopteris*, *Vertebraria* and *Næggerathiopsis* are allied to forms found in Australian strata." I myself had occasion to study the Karharbári beds more closely during an excursion which I made in the summer of 1871 with Dr. Stoliczka. Mr. Heine, a German, was then manager of the collieries at Karharbári. He had just then bared the coal seams in a couple of open workings, and invited us to inspect these workings. We found two seams exposed to daylight (at small depths) in terrace-like steps by the clearing away of the overlying sandstone mass, so that only a thin layer of shale covered the coal itself. The exposed surface measured at the lowest estimate many square metres, and was covered with well-preserved plant remains,—a real joy to the eye of a palæontologist. Unluckily the harvest was not so great as we had expected. It was the hot season; and the shales had been exposed for

several days to the glowing sun and to the furnace blasts of the hot winds, and the rock was in consequence so cracked that it crumbled away under the lightest touch of chisel or hammer. If Mr. Heine had not previously preserved specimens for us, we must have departed empty-handed. The specimens then procured formed the chief basis for Feistmantel's descriptions. Only few geological observations could then be made because of the terrible heat. The beds are all nearly horizon tal, but their relations to the not distant beds of the Damuda coal-basin could not be accurately observed because vast tropical forests cover a great part of that region.

"*Damuda.*—The Damuda series consists of sandstones and shales with coal beds: the floras of the different sub-divisions present but few differences," * * *
Feistmantel has described the following species out of the Damuda series:—

Schizoneura gondwanensis, Fstm.
Phyllotheca Indica, Bunb.
" *robusta, Fstm.*
Trizygia speciosa, Royle.
Vertebraria indica, Royle.
Cyathea cf. tchihatcheffi, Schmalh.
Sphenopteris polymorpha, Fstm.
Dicksonia hughesi, Fstm.
Alethopteris whitbyensis, Goepp.
" *lindleyana, Royle.*
" *phegopteroides, Fstm.*
Pecopteris affinis, McCl.
Merianopteris major, Fstm.
Macrotæniopteris danæoides, Royle.
" *feddeni, Fstm.*
Palæovittaria kurzi, Fstm.
Angiopteridium cf. m'clellandi, Oldh.
" *infractum, Fstm.*
Glossopteris communis, Fstm.
" *intermittens, Fstm.*
" *stricta, Bunb.*
" *musafolia, Bunb.*
" *indica, Schimp.*
" *browniana, Bgt.*
" *intermedia, Fstm.*
" *retifera, Fstm.*
" *conspicua, Fstm.*
" *ingens, Fstm.*
" *divergens, Fstm.*
" *damudica, Fstm.*
" *angustifolia, Bgt.*
" *leptoneura, Bunb.*
" *formosa, Fstm.*
" *orbicularis, Fstm.*
Gangamopteris anthrophyoides, Fstm.
" *whittiana, Fstm.*
" *hughesi, Fstm.*
" *cyclopteroides, Fstm.*
Belemnopteris wood-masoni, Fstm.
Anthrophyopsis, sp.
Dictyopteridium, sp.

Sagenopteris logifolia, Fstm.
,, *polyphylla, Fstm.*
Actinopteris bengalensis, Fstm.
Pterophyllum burdwanense, M'Cl., sp.
Anomozamites, sp.
Næggerathiopsis hislopi, Fstm.
Rhipidopsis densinervis, Fstm.
Voltzia heterophylla, Brgt.
Samaropsis cf. parvula, Heer.

Besides these a few animal remains were found, *viz.*—

Estheria mangaliensis, Jones.
Brachyops laticeps, Owen.
Gondwanosaurus bijorensis, Lyd.

Of these remains there is nothing more to be said than that *Brachyops* is more or less nearly related, while *Gondwanosaurus* approaches very closely to *Archegosaurus.*

"The most abundant of the above-named fossils are *Glossopteris* and *Vertebraria.* With the exception of *Næggerathiopsis,* all the cycads and conifers are of excessive rarity. More than one-half of the species known are ferns with simple undivided fronds and anastomosing venation."

"For many years European palæontologists generally classed this flora as Jurassic. This was the view accepted by De Zigno and Schimper, and, though with more hesitation, by Bunbury. The species of *Phyllotheca, Alethopteris* (or *Pecopteris*), and *Glossopteris* (allied to *Sagenopteris*) were considered to exhibit marked Jurassic affinities. It was generally admitted that the Damuda flora resembles that of the Australian coal-measures * * * * more than it does that from any known European formation; but the Australian plants were also classed as Jurassic. There is no reason for supposing that the more recent discoveries of Damuda plants would have modified this view; the identification of such forms as true *Sagenopteris* and the cycads *Pterophyllum* and *Anomozamites* would assuredly have been held to confirm the Jurassic age of the beds. So far as European fossil plants are concerned, the Damuda flora resembles that of the Middle or Lower Jurassics more than any other.

"One form, it is true, the *Schizoneura,* is closely allied to *S. paradoxa* from the Bunter or lower Trias of Europe. Other plants have Rhætic affinities. But the connections with the Triassic flora do not seem nearly equal to those shown with Jurassic plants, and the reason that the Damuda flora has been classed as probably Triassic must be sought in the impossibility of considering it newer, if the next overlying stage is classed as Upper Trias or Rhætic, and in the close affinity with the underlying Karharbári beds, which contain several Lower Triassic types.

"*Panchet.*—The uppermost series of the Lower Gondwanas consists chiefly of sandstone, and fossils are rare. The most interesting are remains of *Reptilia* and *Amphibia.*" The following is a list of the faunna and flora:—

Epicampodon indicus, Huxley, sp.
Dicynodon orientalis, Huxl.
Pachygonia incurvata, Huxl.
Gonioglyptus longirostris, Huxl.
,, *huxleyi, Lyd.*

Glyptognathus fragilis, Lyd.
Estheria, sp.
Schizoneura gondwanensis, Fstm.
Vertebraria indica, Royle.
Pecopteris concinna, Presl.
Cyclopteris pachyrrhachis, Goepp.
Thinnfeldia cf. odontopteroides, Morr., sp.
Oleandridium cf. stenoneuron, Schenk.
Glossopteris communis, Fstm.
,, indica, Schimp.
,, damudica, Fstm.
,, angustifolia, Bgt.
Samaropsis cf. parvula, Heer.

The *Schizoneura*, the *Vertebraria* and the various species of *Glossopteris* are identical with those found in the Damuda beds. Besides them are several species identical with those of the Rhætic beds of Europe, and two others have their nearest relatives in these beds, and thus perhaps the whole flora of the Panchets may be regarded as Rhætic, or at least as Triassic.

"All the genera of *Labyrinthodonts* named are peculiar, their nearest European allies are chiefly Triassic. *Dicynodontia* are only known with certainty from India aud South Africa, but some forms believed to be nearly allied have been described from the Ural Mountains. These fossils were obtained from rocks now referred to the Permian.

"*Upper Gondwanas.*—The different series of the lower Gondwanas are found in the same area resting one upon the other, so that the sequence is determined geologically. This is not the case with the upper Gondwana groups; their most fossiliferous representatives are found in different parts of the country, and the relations to each other are mainly inferred from palæobotanical data. Although, therefore, it is probable that the Rájmahâls are older than the Cutch and Jabalpur beds, and that the Kota-Maleri strata are of intermediate age, it is quite possible that two or more of these series may have been contemporaneously formed in regions with a different flora.

"*Rájmahál.*—The comparatively rich flora of the lowest upper Gondwana series is contained in beds interstratified with basaltic lava-flows of the fissure-eruption type." The following are the genera of plants found :—

Equisetum rajmahalense, Schimp.
Gleichenia bindrabunensis, Schimp.
Danæopsis rajmahalensis, Fstm.
Dicksonia bindrabunensis, Fstm.
Hymenophyllites bunburyanus, Oldh.
Pecopteris lobata, Oldh.
Sphenopteris hislopi, Oldh.
,, membranosa, Fstm.
Cyclopteris oldhami, Fstm.
Thinnfeldia indica, Fstm.
Asplenites macrocarpus, Oldh.
Macrotæniopteris crassinervis, Fstm.
,, lata, Oldh.
,, morrisi, Oldh.
,, ovata, Schimp.

Angiopteridium spathulatum, *M'Cl.*, *sp.*
„ *m'clellandi*, *Oldh.*, *sp.*
„ *ensis*, *Oldh.*, *sp.*
Rhizomopteris balli, *Fstm.*
Lycopodites gracilis, *Fstm.*
Pterophyllum carterianum, *Oldh.*
„ *crassum*, *Morr.*
„ *distans*, *Morr.*
„ *kingianum*, *Fstm.*
„ *medlicottianum*, *Oldh.*
„ *propinquum Goepp.*
„ *rajmahalense*, *Morr.*
Anomozamites fissus, *Fstm.*
„ *morrisianus*, *Oldh.*, *sp.*
„ *princeps*, *Oldh.*, *sp.*
Zamites proximus, *Fstm.*
Ptilophyllum tenerrimum, *Fstm.*
Otozamites abbreviatus, *Fstm.*
„ *bengalensis*, *Schimp.*
„ *oldhami*, *Fstm.*
Dictyozamites indicus, *Fstm.*
Cycadites confertus, *Oldh.*
„ *rajmaholensis Oldh.*
Williamsonia cf. gigas, *Cerr.*
„ *microps*, *Fstm.*
Cycardinocarpus rajmahalensis, *Fstm.*
Palissya conferta, *Oldh.*, *sp.*
„ *indica*, *Oldh.*, *sp.*
Cheirolepis cf. münsteri, *Schimp.*
Araucarites macropterus, *Fstm.*
Cunninghamites, *sp.*
Echinostrobus rajmahalensis, *Fstm.*

"The marked change from the Lower Gondwana floras is visible at a glance; not a single species is common to both, most of the genera are distinct, and the difference is even greater when the commonest plants are compared. In the Lower Gondwanas the prevalent forms are *Equisetaceæ* and ferns of the *Glossopteris* type, whilst in the Rájmahál flora cycads are by far more abundant than any other plants. The whole assemblage, moreover, is more nearly allied than are any of those in the Lower Gondwana beds to European mesozoic floras.

"Of the Rájmahál plants about fifteen are allied to Rhætic European forms, three to Liassic or lower Jurassic (two of these having also Rhætic affinities), and six to Middle Jurassic (two having Rhætic relations as well). The flora must therefore, as a whole on purely palæontological grounds, be classed as Rhætic."

Although Professor Feistmantel wishes to have the Rájmahál beds also regarded as Liassic, he cannot adduce any cogent reasons for it; though it is not meant to imply hereby that these beds might not in part be contemporaneous with liassic formations.

"*Kota Maleri.*—The deposits belonging to this series are found in the Godavari valley at a considerable distance from the Rájmahál hills in Bengal, the locality for the Rájmahál flora. Both Rájmahál and Kota-Maleri beds overlie rocks of the Damuda series. It is not quite clear whether the Kota beds, which contain fish, insects, and crustaceans, and the Maleri beds, in which remains of fish, reptiles, and plants are found, are interstratified, or whether the Kota beds overlie those of

Maleri. That the two are closely connected is generally admitted." From the Maleri beds the following remains have been recorded :—

Hyperodapedon huxleyi, Lyd.
Parasuchus hislopi, Lyd.
Pachygonia cf. incurvata, Huxl.
Scuta of undetermined Labyrinthodonta.
Ceratodus virapa, Oldh.
,, *hunterianus, Oldh.*
,, *hislopianus, Oldh.*
Lepidotus pachylepis, Eg.
,, *calcaratus, Eg.*
,, *deccanensis, Sykes, Eg.*
,, *longiceps, Eg.*
,, *breviceps, Eg.*
Tetragonolepis oldhami, Eg.
,, *analis, Eg.*
,, *urgosus, Eg.*
Dapedius egertoni, Sykes.
Estheria kotahensis, Jones.
Candona kotahensis, Jones.
Angiopteridium spathulatum, M'Cl.
Ptilophyllum acutifolium, Morr.
Cycadites, sp.
Palissya conferta, Oldh.
,, *jabalpurensis, Fstm.*
,, *indica, Oldh.*
Chirolepis, sp.
Araucarites cutchensis, Fstm.

In South Rewa remains of *Belodon* and (?) *Thecodontosaurus* were found in beds of probably similar age, while from Denwa a *Mastodonsaurus* has been described.

"The fish are Liassic forms." The reptilia of the Maleri beds are on the other hand triassic. "*Ceratodus* is chiefly triassic." But it occurs also in the Permian and Jurassic. The plants show relations with both the Rájmahál and Jabalpur floras; and as the palæontological relations to beds in the same country are considered far higher in importance than those to deposits in distant regions, the Kota Maleri beds are classed as intermediate between the Rájmahál and Jabalpur epochs.

"*Cutch* and *Jabalpur*.—The Jabalpur beds are found in Central India to the south of the Nerbudda valley, and form the highest true Gondwana beds. The Cutch beds, as already mentioned, are found interstratified with marine deposits of uppermost Jurassic age far to the westward, a little east of the mouths of the river Indus. The similarity of the plant remains in the two series has caused them to be classed together, but it is not certain that they are really of contemporaneous origin." Similar beds have also been found in South India on the east coast near the mouth of the Godavari, but their flora is already somewhat differentiated.

The following species have been determined up to date out of the Jabalpur beds :—

Sphenopteris cf. arguta, L. and H.
Dicksonia, sp.

Alethopteris lobifolia, Schimp.
" medlicottiana Oldh.
" whitbyensis, Göpp.
Macrotæniopteris, sp.
Glossopteris cf. communis.
Sagenopteris, sp.
Podozamites lanceolatus, L. and H.
" spathulatus, Fstm.
" hacketi, Fstm.
Otozamites hislopi, Oldh.
" gracilis, Schimp.
" distans, Fstm.
" angustatus, Fstm.
Ptilophylium acutifolium.
" cutchense, Morr.
Pterophyllum nerbuddiacum, Fstm.
Williamsonia cf. gigas, Corr.
Cycadites cf. graminens, Heer.
Palissya indica, Oldh.
" jabalpurensis, Fstm.
Araucarites cutchensis, Fstm.
Brachyphyllum mamillare, L. and H.
Echinostrobus expansus, Schimp.
Taxites tenerrimus, Fstm.
Ginko lobata, Fstm.
Czekanowskia, sp.
Phœnicopsis, sp.

Of these plants six are identical with species from the lower Oolite of England, and a few others are nearly related to the same. The occurrence of *Glossopteris* and *Sagenopteris* gives a somewhat archaic aspect to the whole flora. Besides the above are four species, which are identical with four others from the Rájmahál beds.

The following fossil plants were procured in the peninsula of Cutch:—

Chondrites dichotomus, Morr.
Oleandridium vittatum, Brgt.
Tæniopteris densinervis, Fstm.
* *Alethopteris whitbyensis, Brgt.*
Pecopteris tenera, Fstm.
Pachypteris specifica, Fstm.
" brevipinnata, Fstm.
Actinopteris, sp.
* *Ptilophyllum cutchense, Morr.*
* *" acutifolium, Morr.*
" brachyphyllum, Fstm.
Otozamites contiguus, Fstm.
" imbricatus, Fstm.
" cf. goldiæi, Brgt.
Cycadites cutchensis, Fstm.
Williamsonia blanfordi, Fstm.
Cycadolepis pilosa, Fstm.
Palissya boojoorensis, Fstm.
Pachyphyllum divaricatum, Bunb.
Echinostrobus expansus, Schimp.

The species marked with asterisks are identical with species from the Jabalpur beds, and it is possible also that one of the unnamed species of *Palissya* may also have to be regarded as identical. Seven are, according to Feistmantel, identical with species from the Lower Oolite of Yorkshire, and further, three very closely related; but probably the identity of only the four is really established.

The plant-bearing beds are in their lower parts interbedded with marine deposits, which represent the upper division of a long series of Jurassic beds, within the limits of which all the zones of the Kelloway, Oxford, and Kimmeridge groups are represented.

The upper bed in particular has yielded the following cephalopoda:—

Haploceras cf. tomephorum, Zitt.
Aspidoceras wynnei, Waagen.
Perisphinctes cf. suprajurensis, Orb.
" *bleicheri, Lor.*
" *occultefurcatus, Waagen.*
" *eudichotomus, Zitt.*

All these are Portland-Tithonian types. The plant-bearing beds are overlaid by Aptian deposits.

This concludes the series of the several divisions of the Gondwana system. To enter further into the controversies as to the real age of these uppermost plant beds would take me beyond the scope of the present work.

The final result of the whole presentment appears to be that there exists in India a great rock system which includes at its base glacial deposits, and which, according to the fossil plants it contains, has been regarded as belonging to the Mesozoic era. But doubts as to this conclusion were advanced because it appeared probable on geological grounds, that the lower divisions of the system were of greater antiquity. W. T. Blanford has sought to prove by arduous and spirited deductions that the Tálchirs and Damudas answer to the Permian of Europe, and in so doing came very near to the truth, but he had no positive proofs; and thus the palæoplytologists were still at liberty to abide by their views, and to regard the type of the floras as determinant of the age of the formations.

Blanford had in his deductions already partially leant upon the presence of the glacial formations.

II.—SOUTH AFRICA.

In the matter of geological details in Africa we are unfortunately much less well-informed than could be desired, or than we are with regard to India. Roughly sketched, the geological structure of South Africa may be represented as a vast sandstone region occupying the entire centre, the margins of which are framed by a broad belt of older formations, crystalline rocks, old slates, and Devonian beds. On the outside edge along the coast small tracts of the central sandstone formation re-appear in isolated patches; here, however, the sandstones are interbedded with marine formations, which are entirely wanting in the central area.

The whole structure itself reminds one strongly of the conditions pertaining in India; and the resemblance becomes yet more striking the more one goes into detail.

It is the central sandstone formation, the so-called Karoo formation, which is

especially interesting. This formation spreads itself throughout the north part of the Cape Colony, the Orange Free State, Natal, the Transvaal, and the deserts lying further westward, and shows a series of sandstones and shales (interrupted here and there by eruptive rocks), which attains a maximum thickness of about 5,000 feet. The basis of the whole system is a rather varied one, as it for the most part rests uncomformably on the older rocks.

Most frequently the basis consists of the so-called Table Mountain sandstones, whose age has been much disputed. They are generally regarded as Devonian, but in an essay which has just appeared, E. Cohen[1] has shown that they should preferably be reckoned to the Carboniferous system. They rest partly in unconformity on clay-slates of probably Silurian age, and partly conformably on the richly fossiliferous Devonian grey-wackes of the Bokkeveld. Other whitish or yellowish sandstones which appear on the Witteberg and Zuurberg, as also near Graham's Town, Winterhock[2] and other places, have yielded remains of *Lepidodendron*. At Tulbagh, in the Cape Colony, these beds contain coal, in which remains of *Calamites*, *Equisetum* and *Lepidodendron* are found.[3]

Overlying these formations unconformably comes the Karoo formation, which often rests directly on the Devonian grey-wackes.

The Karoo formation is reducible to a series of sub-formations, which may be represented as follows according to Wyley's full classification :—

	Stormberg beds	1,800′ thick.
	Beaufort beds	1,700′ „
	Koonap beds	1,500′ „
Ecca beds	Upper Ecca shales	1,200′ „
	Ecca conglomerate	500′—800′ thick.
	Lower Ecca shales	of no great thickness.

The lowest beds of the lower Ecca shales are said to be strongly contorted equally with the sandstones which are connected with them. They occur at the same places with the Carboniferous sandstones above referred to (Witteberg, Zuurberg, &c.) and are reported fossiliferous.

As all the other beds, both over and underlying, are nearly absolutely horizontal and undisturbed, the contorted character of these shales is remarkable. They occur, however, but in few places.

In general, the older deposits are overlaid by the *Ecca conglomerate*, a most remarkable rock, which for many years was regarded as eruptive and called a "trap breccia." Dr. Sutherland was the first who recognized the action of ice in the formation of these beds, but at the time his views met with much objection.[4]

Dr. Sutherland describes the deposit as composed of grey-blue clayey material, in which fragments of granite, gneiss, greenstone, and clay slate are imbedded. These fragments are of very various sizes from little grains of sand to huge blocks, 6 feet in diameter and weighing from 6 to 10 tons. These blocks are generally smoothed, as if they had been to a certain extent ground down in a clayey sediment, but they are not rounded like blocks which have been exposed to surf-

[1] E. Cohen, Neues Jahrb. f. Min. Geol. u. Pal. V. Beil-Band, 1887, p. 195.
[2] Wyley, Quart. Jour. Geol. Soc. Lond., XXIII, 1867, p. 173.
[3] Griesbach., Ibid, XXVII, 1881, p. 57.
[4] Quart. Jour. Geol. Soc. Lond., 1870, Vol. XXVI, p. 514.

action. The fracture of the clayey matrix is not conchoidal; and, in general, the rock shows a certain tendency to obscure wavy bedding. In places the beds show distinct ripple marks. The thickness of this formation is very various, but in some places it attains as much as 1,200 feet.

These conglomerates rest, as a rule, unconformably on the Table Mountain sandstones, and at the surfaces of contact the sandstones are generally marked with deep grooves and scratchings "as if a heavy semi-plastic substance with includ-ed hard and angular fragments had moved across it;" a very drastic description of the effects of a moving ice-mass!

In an upward direction the conglomerates pass quite gradually into the next overlying group of beds.

Upper Ecca Shales.—These are generally dark-grey shales of very considerable thickness with but few intercalated sandstones. Locally they contain coal seams and plant remains are reported not unfrequent, but up to the present only the genus *Glossopteris* has been cited.

Koonap beds.—Brown sandstone and shales, which latter, however, often show greenish tint. Plant remains are common, particularly in the upper beds, but these plants have not yet been described.

Beaufort beds.—Dark red greenish or grey shales, with comparatively few sand-stone deposits, but with all the more numerous reptile-remains. Fish teeth and plant impressions also occur there. The Karoo plant-remains, described by Tate, are said to have come out of these beds, but might just as well have been derived from the Koonap beds. The bed is unfortunately not sufficiently well known. The following species have been described:—

Glossopteris browniana, Bgt.
" *sutherlandi, Tate.*
" *(Dictyopteris ?) simplex, Tate.*
" *(Rubidgea) mackayi, Tate.*
Phyllotheca sp.

At the first glance it is clear that these plants have a great resemblance to those of the Damuda beds. On the other hand, they are also nearly allied to similar species in Australia as will be clearly shown further on.

The fauna of the Beaufort beds is much richer than the flora. Up to the present only vertebrate remains have been found, a complete enumeration of which is given in Owen's Catalogue of the Fossil Reptilia of South Africa, contained in the British Museum.

Three groups in particular are represented—the Dicynodonta, the Theriodonta, and the Dinosauria. We have already seen that Dicynodonta occur in the Indian Panchet beds.

The Stormberg beds.—Thick sandstones of white or light red colour, with sub-ordinate beds of shale and coal seams. Of plant-remains the following species have been described up to the present:—

Pecopteris (thinnfeldiä), Bgt.
" *sutherlandi, Tate.*
Cyclopteris cuneata.
Tæniopteris daintreei.[1]

[1] Dunn, Report on the Stormberg Coalfield. Geol. Mag., 1879, p. 552.

All these are species which occur equally in the uppermost plant-bearing beds of Australia. Of animal remains the skull of a mammal has *imprimis* been described and received the name of *Tritylodon triglyphus*.[1]

Neumayr has shown that this specimen is remarkably near in its alliance to the genus *Triglyphus* of Fraas from the Rhætic bone bed of Würtemberg, and might possibly be, by some, regarded as generically identical.

If all the relations of the Stormberg beds to the extra-African formations be considered, it would appear that of the Indian rocks the Rájmahál and Jabalpur formations should first be reckoned as their equivalents.

The Uitenhage group.—In the interior, the Karoo system terminates with the Stormberg beds; but along the coast, from the southernmost point up to the neighbourhood of Natal and the Tugela river, appear marine beds alternating with plant-bearing beds, which are assigned partly to the Jurassic, partly to the middle and upper Cretaceous periods. The relations of these deposits to the Karoo system are obscure, and have up to the present not been worked out with sufficient care. But nevertheless the beds are of great interest. The cretaceous rocks described by Griesbach and Baily, and which agree most closely with those of South India, we may here conveniently neglect; but the Uitenhage group deserves our attention all the more.

The geological age of this group has been determined with considerable certainty by Neumayr's latest work on this subject,[2] and there can hardly be any doubt that the whole group must be regarded as Neocomian.

The most important fossils with reference to this conclusion, are :—

Olcostephanus atherstoni, Sharpe.
" *baini, Sharpe.*
Crioceras spinosissimum, Hausm.
Hamites africanus, Tate.
Trigonia herzogi, Hausm.
" *ventricosa, Krauss.*
" *conocardiiformis, Krauss.*
Ptychomya implicata, Tate.

The occurrence of *Trigonia ventricosa* in the Indian Tithonian beds of Cutch can, in view of the occurrence of the Cephalopoda just named, hardly effect much change in the above conclusion, though it may indicate the necessity of being careful.

But besides the marine fossils, plant-remains occur also in these beds, and Tate has described the following species :—

Otozamites recta, Tate.
Podozamites morrisi, Tate.
Palæozamia rubidgei, Tate.
Peterophyllum africanum, Tate.
Pecopteris atherstoneii, Tate.
" *rubidgei, Tate.*
" *africana, Tate.*
Asplenites lobata, Oldh.
Sphenopteris antipodum, Tate.
Cyclopteris jenkinsiana, Tate.
? *Arthrotaxites indicus, Oldh.*

[1] Bronns Jahrb., 1884, I., p. 279.

[2] E. Holub and M. Neumayr, Über einige Fossilien aus der Uitenhage—Formation in Süd-Africa. Denkschr. Kais. Akad. d. Wiss. Wien, Vol. XLIV.

Of these species two are identical with Rájmahál species from India. The others are allied partly to Rájmahál species and partly to Scarborough species. As a whole, the flora is considered as Jurassic.

The mere occurrence of *Trigonia ventricosa* in South Africa and India leads us to regard these Uitenhage beds as equivalent to the uppermost divisions of the Cutch Jurassics, the Umia beds, or the Cutch plant beds. The geological conditions are also agreeable to this. In Cutch the chief mass of the plant-beds follows the Tithonian beds, while in South Africa the plant-beds alternate with Neocomian deposits.

This is all that is known about South Africa. On the whole, there appears to be a pretty close agreement with India, but in the former region the conditions have been too little studied to admit of perfectly certain conclusions. It is highly desirable that a survey of South Africa on the Indian pattern should be established.

One uncertainty I must point out specially. According to the earlier writers it appears that the Ecca beds lie unconformably on the older formations, and that from this point a conformable succession of deposits occurs, but lately it has been asserted that they lie conformably on the older rocks, and that the unconformity appears first between the Eccas and Koonaps. As, however, the Carboniferous sandstones appear to occur only here and there, it is probable that in most places an unconformability exists also between the Eccas and the older formations.

III.—Eastern Australia.

Although the existence in Australia of coal seams with many fossils has long been known, the great geological features of the continent have been but little explored, and many questions which one would much like to have answered cannot be solved on the strength of the existing literature. This imperfect knowledge is due partly to the great difficulty of penetrating into the interior, but chiefly to the peculiar stratigraphical conditions of the Australian formations.

The greatest merit for the geological exploration of Australia was due to the late Reverend W. B. Clarke, and it is specially to the sub-divisions established by him for New South Wales, in the first place, that the formations of other districts must be referred.[1]

The Carboniferous formations of Australia must be of very great vertical thickness, but it is hard to make this out from what has been written about them. The succession is not everywhere the same, nor everywhere complete. Generally the carboniferous beds rest unconformably on older rocks (granite, porphyry, &c.), and the newer members often overlap the older. Silurian and Devonian formations are known (the latter limestones with many marine animal remains), but their relations to the carboniferous beds are very obscure. In the interior, and possibly representative of the more easterly marine formations, is a great deposit of yellow sandstones, which up to the present have only yielded *Lepidodendron* and a species

[1] Quite lately an entirely different scheme of formations in New South Wales has been propounded by Mr. T. W. E. David, in a paper read before the Geological Society of London, but his views were objected to in the discussion which followed the reading of the paper. But the carboniferous glacial formations are most minutely described in Mr. David's paper, and their geological horizon confirmed. Quart. Jour. Geol. Soc. Lon. Vol. XLIII, 1887, p. 190.

of *Cyclostigma*. These beds are generally regarded as Devonian. On these, Carboniferous beds are said to rest, here and there, in regular position, but as to this also there is no certainty.

The Carboniferous beds are arranged by Clarke as follows in downward succession:—

Wianamatta beds.
Hawksbury beds.
Newcastle beds.
Muree beds divided into { Upper marine beds. Older coal seams. Lower marine beds.

I shall try to describe each of these divisions rather fully.

Muree beds.—This is, for our present purpose, the more important division; because on the one hand, beds that have been formed under glacial co-operation occur here largely developed, while on the other hand, some of the deposits contain marine fossils which enable one to determine the age of the beds. There is certainly much here that has not yet been sufficiently determined, but some conclusions may be safely drawn from the facts now known.

As stated above, Clarke divides this series into "Upper marine beds," "Older coal seams," and "Lower marine beds." The whole succession of beds is probably best exposed and most accessible at Stony Creek and near Greta, where the Great Northern Railway cuts through these beds and exposes them in several cuttings, and where several bore holes and pits have penetrated the series.

According to R. D. Oldham, the series exposed both at Stony Creek and Greta is one and the same; the wings of a great anticlinal having been pierced. Clarke gives full sections of the coal pits at both places, and from these it is clear that the main mass of the beds there exposed consists of coarse conglomerate and boulder deposits, which include subordinate sandstones and shales, and near the base several coal seams. Below these seams there occur, according to Oldham, other marine conglomerates. Nearly all the beds exposed in these sections are fossiliferous; and marine animal remains as well as plants are contained here and there in the same bed.

The animal remains are all of Carboniferous type, and were fully described by L. G. de Koninck in his "Recherches sur les fossiles paléozoiques de la nouvelle Galle du Sud." In this work 74 species out of 176 have been identified with European carboniferous limestone forms. The most important are:—

* *Productus cora, Orb.*
* ,, *semireticulatus, Mart.*
* ,, *flemingi, Sow.*
,, *undatus, Defr.*
* ,, *punctatus, Mart.*
,, *fimbriatus, Sow.*
* ,, *labriculus, Mart.*
Strophomena analoga, Phill.
* *Orthothetes crenistria, Phill.*
* *Orthis resupinata, Mart.*
,, *michelini, Sow.*
* *Rhynch. pleurodon, Phill.*

* *Athyris planosulcata, Phill.*
* *Spirifer lineatus, Mart.*
* " *glaber, Mart.*
* " *pinguis, Sow.*
* " *convolutus, Phill.*
" *triangularis, Mart.*
" *bisulcatus, Sow.*
* *Spiriferina cristata, Schl.*
" *insculpta, Phill.*
? *Cyrtina septosa, Phill.*
* *Terebratula sacculus, Mart.*

With regard to this list it should be specially remarked that the species against which an asterisk has been placed are distributed through the whole Carboniferous formation, and cannot therefore be used for determining the horizon more closely. Of the remaining species, M. de. Koninck will probably not be able, even now after an interval of ten years, to identify several with their representative European forms, since he has in his splendid work on the Belgian Carboniferous Limestone, admitted so much more accurate and limited an idea of species. It must be noted, however, that even with the wide meaning M. de Koninck then gave to the idea of species, no form could be identified with *Productus giganteus*, so that this whole group of forms is certainly not represented. It is important to lay stress on this, as *Productus giganteus* in particular is one of the most characteristic species of the lower and middle carboniferous series, while it is distinctly wanting in the upper coal-measures. But *per contra*, there appear in Australia numerous forms which are nearly related to forms in the Permian formations of the Salt-Range (India), *e.g.*, species of the genera *Warthia*, *Atomodesma* (*Aphanaia*) and *Martiniopsis*. All these particulars cause the general character of this marine fauna to appear as pointing with great probability to an age corresponding with that of the upper coal-measures of Europe and America.

We shall see in the course of this sketch that in Australia itself other grounds are to be found for this age determination.

According to Dr. Feistmantel's list,[1] the following remains were discovered in these beds :—

Phyllotheca, sp.
Glossopteris browniana, Bgt.
" " *var. præcussor, Fstm.*
" *primæva, Fstm.*
" *clarkei, Fstm.*
" *elegans, Fstm.*
Næggerathiopsis prisca, Fstm.
Aunularia anstralis , Fstm.

Although they mostly show mesozoic characters, these plants are unquestionably found occurring together with the animal remains above enumerated.

Very important in every respect is the information furnished by R. D. Oldham, that the greatest part of the beds containing the above-named plants and animal

[1] Notes on the fossil Flora of Eastern Australia and Tasmania. Trans. Roy. Soc., New-South Wales, 1860.

remains have been formed by the action of ice. Mr. Oldham visited Greta and Stony Creek personally, and described[1] the beds thus :—

"Blocks of slate, quartzite and crystalline rocks, for the most part sub-angular, are found scattered through a matrix of fine sand or shale, and these latter beds contain delicate *Fenestellæ* and bivalve shells with the valves still united, showing that they had lived, died and been tranquilly preserved where they are now found, and proving, as conclusively as the matrix in which they are preserved, that they could never have been exposed to any current of sufficient force and rapidity to transport the blocks of stone now found lying side by side with them. These included fragments of rock are of all sizes, from a few inches to several feet in diameter, the largest I saw being about 4 feet across in every direction as exposed in the cutting, and of unknown size in the third dimension; but I was informed by Mr. Wilkinson that in these same beds he has seen boulders of slate, &c., whose dimensions may be measured in yards.

"It is impossible to account for these features except by the action of ice floating in large masses, and I had the good fortune to discover, in the Railway cutting near Branxton, a fragment beautifully smoothed and striated in the manner characteristic of glacier action, besides at least two others which showed the same feature, though obscurely. This seems to show that the ice was of the nature of icebergs broken off from a glacier which descended to the sea-level."

Such are the conditions which are found in the sections along the railway west of Newcastle, and chiefly near Greta and in the Stony Creek; but this does not exhaust all that has to be said about the Muree beds.

In other parts of the country as near Stroud, Arowa, Port Stephens and Smith's Creek, there is yet another flora which does not occur at Greta, &c., but must certainly be older than that above described. This older flora consists, according to Feistmantel, of the following species :—

Calamites radiatus, Bgt.
Sphenophyllum, sp.
Rhacopteris inæquilatera, Göpp.
" *intermedia, Fstm.*
" *cf. ræmeri, Fstm.*
" *septentrionalis, Fstm.*
Archæopteris wilkinsoni, Fstm.
Cyclostigma australe, Fstm.
Lepidodendron veltheimianum, Stbg.
" *volkmannianum, Stbg.*

These beds appear, according to Clarke's paper on the sedimentary formations of New South Wales (p. 29), to pass down into the *Lepidodendron* sandstone, but the statement is not quite sufficiently clear. According to G. Mackenzie's section of Stroud, published by Feistmantel, marine beds occur again between the plant beds and the *Lepidodendron* sandstones, and contain *Conularia, Fenestella, Productus,* and *Crinoidea,* but this marine fauna has not yet been closely studied.

Feistmantel regards the flora of these beds as certainly indicative that they are of the carboniferous limestone age.

This fact is one more reason for assigning the marine beds of Stony Creek to the age of the upper coal-measures.

[1] Rec. Geol. Surv. Ind. Vol. XIX., p. 44.

The Newcastle beds.—These consist mainly of sandstones with subordinate shales and coal seams. Their sectional thickness is unknown to me, but Clarke in a section of Burragorang gives a thickness of 716 feet. The seams yield a fairly good coal and are worked in numerous pits.

Of organic remains plants seem very common, but marine animals are entirely wanting. Up to the present the following have been described :—

Phyllotheca australis, McCoy.
Vertebraria australis, McCoy.
Sphenopteris lobifolia, Morr.
" *alata, Bgt.*
" " *var. exilis, Morr.*
" *hastata, McCoy.*
" *germana, McCoy.*
" *plumosa, McCoy.*
" *flexuosa, McCoy.*
Glossopteris browniana, Bgt.
" *linearis, McCoy.*
" *ampla, Dana.*
" *reticula, Dana.*
" *cordata, Dana.*
" *wilkinsoni, Fstm.*
" *parallela, Fstm.*
Gangamopteris angustifolia, McCoy.
" *clarkiana, Fstm.*
Caulopteris adamsi, Fstm.
Zeugophyllites elongatus, Morr.
Næggerathiopsis spathulata, Dana.
" *media, Dana.*
Brachyphyllum australe, Fstm.

Of animal remains only one fish, *Urosthenes australis, Dana,* was found.

The beds are most closely connected with the underlying ones, and were only distinguished from the older division because of the absence of marine fossils and because of certain differences in the flora. They probably stand in a similar relation to the Muree beds, as in India the Kárharbári beds do to the Tálchir beds.

These beds are of special interest, as it was they which, together with the underlying Muree beds (whose separation was not at first attempted, but was only introduced by Feistmantel), led to a comparison of the Indian coal-measures with the Australian, and thus caused the former to be regarded as palæozoic. Although Feistmantel has lately attempted to show that the floras of the Damuda beds and of the Newcastle beds do not agree so closely as has been hitherto assumed, yet a large number of the species is identical. Feistmantel places the Damuda beds parallel only with the next higher sub-division, the Hawksbury beds.

The Hawksbury beds.—These are thick coarse-grained sandstones which show singular weathering forms, especially in the upper beds, and often form rock masses which are not unlike ruined castles. At the base, immediately above the Newcastle beds, come dark violet-red marls rarely interrupted by sandstones, while higher up sandstones predominate. They show yellowish or reddish to reddish-brown colours and pass frequently into conglomerates. Beds of brown ironstone in part impregnated with carbon are not rare, some attain great thickness and are then mined.

The total thickness is given by Clarke at 800 to 1,000 feet.

Fossils are not common in this sub-division, only a couple of fishes and a few plants having as yet been found. They represent the following species:—

Cleithrolepis granulatus, Eg.
Myriolepis clarkei, Eg.
Thinnfeldia odontopteroides, Fstm.
Sphenopteris, sp.
Odontopteris, sp.

It is noteworthy that in these beds again traces of ice-action are recorded. The shale beds often show a very peculiar structure. Great angular blocks of shale are often met lying together in great confusion, the spaces between them being filled with sand or small gravel. Wilkinson,[1] who first drew attention to this believes that great moving masses of ice were the cause of these appearances, that in other words they are appearances caused by the stranding of ice floes.

That ice action participated in the formation of this deposit was also confirmed by Haast.[2]

As mentioned above, the Hawksbury beds were correlated by Feistmantel with the Indian Tálchirs, and perhaps partly with the Damudas. This correlation is however not based on palæontological data, but on the fact that traces of ice-action are found in both formations. This correlation has, however, been lately much called in question by R. D. Oldham,[3] and it must be conceded that such correlation is not a very natural one. But it appears equally unnatural to correlate the Newcastle beds with the Damudas, as is done by Oldham. Much the most probable correlation is to regard the Tálchirs as the equivalent of the Muree beds, and the Kárharbáris as equivalent of the Newcastle beds. *Gangamopteris* and *Glossopteris* occur frequently in both formations, and *Gangamopteris* is common to both. The Damudas would then appear to have to be considered as of Hawksbury age, but the possibility must not be lost sight of that the Damudas may yet in part reach down to the Newcastle beds.

Wianamatta beds.—According to Clarke, these beds appear to follow the Hawksbury's with imperfect conformity; and here appears for the first time a break in sequence of the Australian coal-measures. The Hawksburys appear to have been considerably denuded before the Wianamattas were deposited. These latter consist mainly of soft shales and fine-grained sandstones which give rise to hills of rounded outline. I can nowhere find any statement of their thickness.

In the shales as well as in nodules of spherosiderite, fish and plant-remains are found, and up to the present the following species have been identified:—

Palæoniscus antipodeus, Eg.
Cleithrolepis granulatus, Eg.
Thinnfeldia odontopteroides, Fstm.
Odontopteris microphylla, McCoy.
Pecopteris tenuifolia, McCoy.
Macrotæniopteris wianamatta, Fstm.

This flora is regarded by Feistmantel as Triassic, and treated as equivalent to the Indian Damudas.

[1] Trans. Roy. Soc. New South Wales, 1879 and 1884, XIII, p. 105.
[2] Feistmantel, Rec. Geol. Surv. Ind. XIII, pp. 251-2.
[3] Rec. Geol. Surv. Ind. XIX, pp. 42-45.

The occurrence of *Thinnfeldia odontopteroides*, however, appears to me to point rather to a relationship with the Panchets. Of the fishes, *Palæoniscus* is generally regarded as Permian, while *Cleithrolepis* reminds one more of Mesozoic forms.

On the whole, the series of formations in New South Wales terminates with the Wianamatta beds: it is only here and there that yet younger beds have been found. Such beds have been described by Wilkinson as occurring in the Clarence River, and Feistmantel refers to two species of plants derived from them:—

Tæniopteris daintreei, McCoy.
Alethopteris australis, McCoy.

Both these species are important for the correct classification of particular formations which have been found elsewhere in Australia.

So far this sketch has had reference only to the succession of deposits in New South Wales, but we must turn our eyes towards the other provinces of Eastern Australia. In Queensland, coal-measures are known belonging to two periods. The older of these, which lies more to the north, contains marine fossils of Carboniferous type and remains of *Glossopteris*, *Schizopteris* and *Pecopteris*. In these formations also traces of ice-action have been pointed out.[1]

The more southerly coal-measures are younger in age, and their flora shows the following species:—

Sphenopteris elongata, Carr.
Thinnfeldia odontopteroides, (Morr.) Fstm.
Cyclopteris cuneata, Carr.
Tæniopteris daintreei, McCoy.
Sagenopteris rhoifolia, Presl.
Otozamites cf. mandelslohi, Kurr.
Cardiocarpum australe, Carr.

Feistmantel correlates the beds containing this flora with the youngest beds in New South Wales as seen in the Clarence River.

In Victoria the series is rather more complete. At the base are sandstones, which are specially well exposed at Iguana Creek, and which should probably be regarded as Devonian. They have yielded the following plant species:—

Sphenopteris iguanensis, McCoy.
Aneimites iguanensis, McCoy.
Archæopteris howitti, McCoy.
Cordaites australis, McCoy.

Over these follow sandstones known as the Avon River sandstones, which have yielded *Lepidodendron australe*. Feistmantel considers these formations to be Carboniferous.

The next higher sub-division is of great importance. It bears the name of the Bacchus-Marsh sandstone, and includes great boulder deposits of unquestionably glacial origin. The plant-remains furnished by the sub-division are—

Gangamopteris obliqua, McCoy.
" *angustifolia, McCoy.*
" *spathulata, McCoy.*

Feistmantel has connected these beds with the Hawksbury beds of New South

[1] R. L. Jack, Report on the Bowen-River Coalfield, Brisbane, 1879.

Wales; but it appears much more natural to correlate them with the Muree and New castle beds, and all of them with the Tálchir-Kárharbáris of India.

The uppermost division recognised in Victoria is that of the Bellarine beds. They are very widespread and are of great thickness. Coal seams occur, but are of small thickness and extent. Plant-remains appear to be numerous, and up to the present the following species have been described :—

Phyllotheca australis, Bgt.
Alethopteris australis, Morr.
Tæniopteris daintreei, McCoy.
Podozamites barklyi, McCoy.
Zamites ellipticus, McCoy.
„ longifolius, McCoy.

This flora points with great probability to a Mesozoic age of the beds containing it, and Feistmantel correlates also the Bellarine beds with those on the Clarence River in New South Wales, and the upper coal-measures in Queensland. In India the Rájmahál and Jabalpur beds should probably be considered equivalents of the formations first named.

The above are rough outlines of the conditions met with in South Africa, India, and Australia, and it will be well to bring together in tabular form the results obtained up to the present, in order to obtain a general view before we proceed to make further deductions :—

	South Africa.	India.	Eastern Australia.
Neocomian	Uitenhage .... ?	Cutch . Plant beds.	? Marine beds in Queensland.
Tithonian.		Marine beds, Tithonian.	
? Rhætic and Jurassic.	Stormberg beds.	Jabalpur beds Kota Maleri beds Rájmahál beds	Bellarine beds. Clarence River beds. Southern coalfields, Queensland.
? Lowest Trias.	Beaufort beds	Panchet beds	Wianamatta beds. *Unconformity.*
Permian.	Koonap beds	Damuda beds	Hawksbury beds (glacial).
Upper Carboniferous.	*Unconformity*	Kárharbári beds	Newcastle beds.
	Ecca beds (glacial)	Tálchir beds (glacial)	Stony Creek beds. Bacchus Marsh beds (glacial).
Lower Carboniferous.	Lepidodendron beds	Resting unconformably on crystalline rocks.	Stroud and Port Stephen's beds, &c.
			Lepidodendron beds.
Devonian.	Marine Devonian	......	Marine Devonian.

From what has been said above it is evident that in South Africa, equally with India and Eastern Australia, great rock systems occur, which are rather nearly related to each other, and certainly agree with each other far more closely than with any series yet known in Europe or America. The greater part of these formations are evidently of fresh-water origin; and huge lakes and vast river systems must have occupied the regions where to-day we find the formations in question.

This observation led long since to the assumption of a great continent which in early geological periods extended over a great part of the southern hemisphere, and which in area may not have been greatly less than the present Asia-European continent.[1]

The story of this continent seems to have been a highly singular one. Instead of the great chains of foldings which compose the mountain elevations in the northern hemisphere, and form thus to some extent the skeleton of the continents; we here find table-shaped mountains built up of horizontal rock masses. These, it is true, rest on folded rocks, but the rocks effected by the folding action are principally archaic. Already in the Devonian period we see the intensity of the folding forces greatly decreased, great regions like South Africa and India show the Devonian formations mostly in horizontal positions, and whatever followed was only tilted out of its horizontal position here and there quite locally.

While the fold-making action was decreasing more and more on this part of the earth's surface, immense fallings-in appear simultaneously to have led more and more to the breaking up of the once existing vast continent. We know from the distribution of the marine deposits, that in the Jurassic period the old continents had already been separated into three independent parts; and that Africa, India, and Australia were already divided by arms of the sea: in the Triassic period on the contrary, Africa was probably still connected with India, but Australia had already then become independent.

Thus instead of increasing, the old continents shrank more and more; and probably somewhat at the same rate at which Europe and Asia emerged from the sea, the latter overflowed immense areas that were formerly *terra firma*.

At the present day only small fragments remain of the once existing southern continent, but these by the thickness of the horizontally-bedded fresh-water-formations and the mightiness of the physical processes which they reveal, allow us to draw conclusions as to the vast extent of the land to which they once belonged.

The rock systems above treated of were none of them deposited till after the cessation of the folding action. We find all the beds nearly horizontal, forming either plateau regions, or occupying shallow basins, and important stratigraphical disturbances are either local or only to be enumerated as exceptional cases of rare occurrence. The period of the fallings-in had commenced before the formation of the above described rock systems had been finally completed. Vast areas, which had formerly been *terra firma*, were more and more submerged; and the witnesses of these events are the scanty marine deposits of jurassic and cretaceous age which we still meet with along the margins of the few remaining fragments of the ancient continent in Africa, India, and Australia.

[1] H. F. Blanford, Quart. Jour. Geol. Soc. Lond. XXXI, 1875, p. 519. Waagen Denkschr. Kais. Akad. d. W. Wien, 1878. Waagen, Rec. Geol. Surv. Ind. 1878.

It was on this continent that in times long gone by events transpired which remind one strongly of the events which happened during the quarternary glacial period in the northern hemisphere; and there was probably a time when this southern continent was mainly covered with vast masses of ice.

But when was that time? This is the great question that we have now to approach.

It has already been pointed out repeatedly that the palæontological finds in the above-described rock systems give remarkably contradictory results. If we turn merely to the Uitenhage and Cutch beds, we find in them a marine fauna pointing to a Neocomian and Tithonian age for those formations; while the plant-remains met with in the same beds are universally judged as pointing to a lower Oolitic age, and specially to the horizon of the Scarborough beds.

These contradictions between the animal and vegetable remains recur more or less in all the different sub-divisions of the systems, and become very markedly conspicuous in the Autralian Muree beds, where again marine deposits occur alternating with plant beds.

The fossil plants occurring in these beds were, and are still to-day, pronounced by McCoy, to be positively mesozoic; because in Europe the genus *Glossopteris* has only been found in the Russian Jura and in Tertiary formations, and could therefore hardly be of greater than mesozoic age in Australia. When at a later date, Feistmantel condescended to admit the Australian formations into the palæozoic epoch, it was done far less because the flora required it, than because of the marine animal remains occurring in these beds, which have a distinctly palæozoic character. But as the succession of beds, whether above or below the disputed formations, yielded no perfectly certain data for determining the age; the followers of the mesozoic age theory were at liberty to-say "the plant-remains point distinctly to a mesozoic age of the entire system, and thus it is probable that in Australia the palæozoic animal forms survived longer than in Europe, and reached up into mesozoic times." In support of this the fact could be adduced that in the present fauna and flora of Australia old types reaching up from earlier times are for the most part common, and that therefore in earlier times other old types might there be found reaching up higher than elsewhere. On the other hand, however, the species in M. de Koninck's work were so widely framed that the designation of species there used could really only be valid as group names. I myself was for some time not quite disinclined to join in these views of the phytopalæontologists, for which reason I have here and there spoken of the "So called-carboniferous deposits of Australia."

The question as to the age of these beds is now, however, of quite special interest, because of the glacial formations which are met with at equivalent horizons.

As I have already memtioned above, W. T. Blanford has striven with much skill to make a Permian age probable for the Tálchir-Kárharbári-Damuda series, and for the equivalent beds in Africa and Australia; but it was impossible for him to adduce anything more than proofs of probability, and thus no further conclusion could be based on his deductions.

It was reserved for recent times to clear up the subject; and it was the discoveries, more especially of the Würtembergian, Dr. H. Warth, in the Salt-Range which let the whole question appear in a new light.

IV.—THE SALT-RANGE.

It has long been known that in the Salt-Range also, formations are not seldom met with which have doubtless been formed under the co-operation of ice.

I have myself seen and studied these formations in many places, but till now had no opportunity of expressing my opinions about them publicly. Even now I feel somewhat embarrassed about speaking on this subject, for a remarkably unlucky star rules over everything that I publish on the general relations of the Salt-Range. Every time I am rebuffed in a manner that is really not seemly. Expressions such as "ignorance," "charlatanism," or "it would be best to regard such a paper as unpublished," are among the terms of endearment I am thought worthy of. If the writers of these knew how that I take counsel with myself for years, and consider from all points any important view before I publish it, they would perhaps judge me more indulgently. Hitherto it has not been possible for them to disprove my position; consequently I feel myself justified in still holding fast to the views which have given occasion for such harsh criticism.

The succession of beds in the Salt-Range, includes as is well known, the rock systems from the Eocene to about the Devonian (not to refer to the younger tertiary sandstones of the Potwar plateau) without showing any specially important gaps. It is equally well known that in different parts of the Salt-Range the succession of beds is very variously represented. I must here also use the nomenclature introduced by Wynne, as the application of European terms would involve too concrete a correlation, and does not at the present moment seem quite desirable.

In the eastern part of the Salt-Range the succession is as follows:—

Nummulitic beds.
Olive group.[1]
Beds with salt crystal pseudomorphs.
Magnesian sandstone.
Neobolus beds.
Purple sandstone.
Salt-marl and rock-salt.

Except the neobolus beds, the olive group, and the nummulitic limestone; this whole series of beds has yielded hardly any organic remains worth naming, and it would have been hardly possible to have determined the age of any one group in this succession from such evidence as existed till quite lately.

In the western part of the Salt-Range on the contrary, matters were quite different, as some beds occur here rich in well-preserved and characteristic fossils. The succession of beds here is the following:—

Nummulitic beds.
Olive group.
Variegated sandstone (Jurassic).
Ceratite beds.
Productus limestone (Permian).
Speckled sandstone.

[1] This term is now discarded; the greater part, if not the whole, in certain localities, of the series being now known as the "speckled sandstones."—*Ed.*

Magnesian sandstone } hardly separable here; they thin out westward.
Neobulus bed }
Purple sandstone, thinning out westward.
Salt-marl and rock-salt.

The sub-division is seen to be much more varied here, and the age of several of the formations can be accurately determined. For our present purpose the "speckled sandstone" is the most important, and we will consider it more closely. By the "speckled sandstone" I understand not only what Wynne called by this name in the Salt-Range proper, but also the equivalents on this horizon in the west (the boulder group) and in the east as well (the olive group in part).

For clearer comprehension of the succession, however, it must be pointed out that the nummulitic beds and the olive group (more correctly the *Cardita beaumonti* beds) rest unconformably on all the underlying groups, and thus, if followed from west to east, they lie successively on Jurassics, ceratite beds, Permians and speckled sandstones—a circumstance which in part also causes the difference in the succession of beds in the eastern and western parts of the range. Besides this I must here rely entirely on Wynne's report, as all my own observations are woven into it. The report is in fact to be regarded as a joint one, as far as the observations in the field have to be considered. It should have been a joint one in its execution, but this was prevented by my repeated serious illnesses; and thus Wynne was compelled to undertake the working out of it by himself. The employment of the material has in consequence certainly often led to the different results, as if I would have disposed of them could I have influenced their being worked out. I cannot, however, for that reason entirely give up my own views, and Mr. Wynne must allow me to give them expression here and there. It is very far from my intention to ignore, on that account, the great credit Mr. Wynne has deserved by the working out of the map; or to fail to acknowledge the admirable accuracy of his map. But now, if after having worked out the fossil faunas of the Salt-Range in great measure, I find myself constrained to lay yet greater stress on various points in the apprehension of which I did not agree with Mr. Wynne; it will be owing to the progress made through the more exact understanding, palæontologically, of the beds. Mr. Wynne cannot possibly wish to assert that it is impossible to attain to a better knowledge of the beds than that given in his report, and doubtless his own views will have become clearer within the last ten years, as is the case with every savant unless he absolutely closes his ear against all progress.

As I stated im my introduction to the Salt-Range Fossils, the palæozoic formations of the Salt-Range are divisible into two great groups, of which the one consists of the purple sandstone and the salt-marl, the other of the higher-lying beds.[1]

[1] R. D. Oldham believes (according to a friendly communication from him) that he can show an unconformability below the speckled sandstone, while the underlying beds down to the saline series form a consistent and conformable series. As far as the unconformability is concerned, I have no objection to make to it; on the contrary, I believe I myself made observations which allow it to appear probable, at least at certain points; but I nevertheless believe that all the beds underlying this break cannot be regarded as belonging to one group. The magnesian sandstone and neobolus beds belong together, as certainly as it is sure that their fauna is related to that of the overlying beds although they are unconformable. But the purple sandstone shows such very close relation to the saline series, that the two can hardly be separated. The base of the latter is not exposed in the Salt-Range proper. Proceeding westward, the saline

The upper group, on the contrary, includes many littoral formations and may have been deposited by a sea that advanced from the north-west. The immense sandstone accumulations to the east of the Salt-Range, which thin out to inconsiderable beds and almost die out, appear to me to be explicable as "dune" formations, and I further believe that they indicate the embouchure of a great river which flowing from the south-east, in those long-past times reached the sea in this region. There are many points on which to base such an assumption. *Imprimis*, the Neobolus beds, as the horny-shelled Brachiopods, had probably lived in the same kind of places as the existing *lingulæ* which frequently colonize the muddy or sandy bottoms in the vicinity of river mouths; and secondly, the beds with pseudomorphic salt crystals, which indicate a tract overflowed alternately by fresh and salt water, conditions which appear most frequently in lagoons surrounding estuaries.

Under these sandstone formations, the speckled sandstones are, as pointed out above, those which extend furthest to the west, and which for many other reasons are the most important and interesting. In their uppermost beds they include a marine fauna which is very nearly related to the fauna of the Productus limestone, and for which reason I designated this formation the Lower Productus limestone. The percentage of true carboniferous species in these beds is greater than in the Productus limestone proper, and I have therefore thought it necessary to join these beds to the coal-measures specially as *Fusulina longissima, Möll.*, occurs here numerously. Perhaps they should only be correlated with the very uppermost beds of this group, *e.g.*, the Nebraska beds or the Artinsk sandstones, because of the frequent occurrence of the genera *Strophalosia* and *Aulosteges*.

Somewhat lower down in these sandstones occur boulder beds, which are to the northward and westward, the only representatives of the whole group, and occur there very constantly below the fossiliferous beds and the Permian limestones.

Unfortunately I cannot, with reference to these boulder formations, enter into as full detail as might appear desirable, partly because of the excessive length this paper would then acquire, partly for the reason that in the last volume of the Salt-Range Fossils a detailed sketch of the Salt-Range will be given, which must not be anticipated here.[1]

series continues to include more and more grey dolomites and gypsums with quartz crystals, and west of the Indus seems to pass into Wynne's generally grey-coloured upper gypsum and dolomite group. The base of this group, however, consists again of red sandstones identical with the purple sandstones of the Salt-Range proper. Thus the saline series appears altogether to be only an inclusion in a vast formation of red sandstone, which must clearly be regarded as a distinct formation. I regard this formation as an equivalent of the Vindhyans of the Indian peninsula; and from its position below the Carboniferous neobolus beds, as of Devonian age. The two groups have a very different distribution, the older occurs only in the south, and disappears in part where the other trends to the north; it would appear that the beds composing this group were formed in a great basin which extended south-eastward, probably an inland basin, and that the open sea of that part would have to be sought for further to the north.

[1] A considerable amount of new information concerning this boulder bed has in the meantime been gained through the work of Dr. Warth and R. D. Oldham (See Rec. G. S. of I., XIX, pp. 1, 22, 127, 131; XX. p. 117; XXI, p. 34). while I myself can further supplement this by my own observations this year of the decided unconformity of this boulder-bed to the underlying Salt-Pseudomorph zone, in the Khewra portion of the Salt-Range, where also, the Talchir facies of the boulder bed is remarkable.—W. K.

To the west (Trans-Indus), especially near Kingriali, Wynne distinguishes a very peculiar boulder group consisting of grey clays with subordinate sandstones and gypsums, and containing in its upper part a boulder bed of considerable thickness. The boulders are well smoothed and often marked by scratches. This boulder group is followed here as elsewhere above the speckled sandstones by the Permian limestones.

To the north-east of this lies Kalabagh, which indicates the most northerly point to which the range has deviated from its general course. Here also on the left bank of the Indus begins the Salt-Range proper, with a group of hills called the Tredian hills. Here the conglomerates are specially well developed, and are described by Wynne as follows: [1]

"The carboniferous limestones below often contain much chert, both black and white; while grey conglomerates and sandstone bands occur in the dark conglomeratic purple clay above the salt-marl. * * * * Immediately over the earthy part is a large boulder-conglomerate containing blocks of granite, syemite, and other crystalline rocks 2 feet in diameter; this conglomerate, if it has not slipped upon itself, may be 155 feet in thickness." Above this occur traces of the speckled sandstone.

We herewith enter upon the domain of the true speckled sandstone. This section is, as Wynne himself describes it, conglomeratic in many places, and the conglomerates appear frequently as true boulder accumulations, particularly in the region of Makrach and Sardi. As is usually the case, these boulder beds are not too regularly stratified, and it is hard to say whether they occur at absolutely the same horizon at different places; they are, however, irrespective of small vertical differences, geologically speaking of the same age. The position is always such that one must conceive the boulder beds as underlying the *Fusulina* beds.

The speckled sandstone attains its greatest development between Varcha and Narsingpohar, and from there thins out rapidly to the eastward, but without losing its boulder accumulations. Quite gradually, the intercalated clays assume a red colour, but the boulder beds become green; and thus two new groups are developed, namely, the "pseudomorphic salt-crystal zone and the conglomerates of the olive group." The most western point from which Wynne quotes the boulder conglomerates of the "Olive group" is Karuli. Here they lie upon the speckled sandstone, and probably on the middle division of that group. Still further to the west the olive group is, it is true, also clearly developed, but here, as for example at Nilawan, it rests on the fossiliferous beds of the Lower Productus limestone. No trace exists of any boulder formations at the base of the group, and we must descend to the speckled sandstone to find any such again.

The boulder conglomerates of the olive group have of late attracted special attention, as fossils have been found in them which agree with fossils obtained from the Australian marine Carboniferous beds. I published a note [2] on these, but by so doing again stirred up a hornet's nest, and was rebuffed by R. D. Oldham in anything but a civil style.[3]

The olive series, as described by Wynne, contains in its upper division an equi-

[1] Mem. Geol. Surv. Ind., Vol. XIV, p. 258.
[2] Rec. Geol. Surv. Ind., XIX 1886, p. 2.
[3] Rec. Geol. Surv. Ind., XIX, part II.

valent of the *Cardita beaumonti* beds of Sind; in the lower division the much contested boulder beds. In these latter, nodules[1] of clayey sandstones were discovered by Warth, which contain inumerable specimens of *Conularia.*

These nodules form a thin bed in the uppermost part of the boulder bed, and have up to the present yielded the following fauna:—

Bucania cf. kattaensis, Waagen.
Conularia lævigata, Morr.
 „ *tenuistriata, McCoy.*
 „ *cf. irregularis, Kon.*
Nucula sp. ind.
Atomodesma (?) warthi, Waagen.
Aviculopecten cf. limæformis, Morr.
Discina, sp.
Serpulites warthi, Waagen.
 „ *tuba, Waagen.*

To these I can now add *Spirifer vespertilio, Sow.*, from specimens recently sent over by Dr. Warth. This entire fauna is distinctly palæozoic, and there is not a single species present pointing to other formations. Four of the species are identical with Australian carboniferous species, namely:—

Conularia lævigata, Morr.
 „ *tenuistriata, McCoy.*
Aviculopecten cf. limæformis, Morr.
Spirifer vespertilio, Sow.

A *Bucania cf. kattaensis, Waagen,* is comparable with another out of the uppermost divison of the speckled sandstone, the so-called lower productus limestone.

According to Wynne and Oldham, these nodules occur as washed-up specimens. And as chief proof of this the rare occurrence of rolled specimens of *conularia* is adduced, and also the fact that the nodules do not contain the organic remains in their centre like proper concretions, but that the fossils appear cut off by the surface of the nodules in the most various ways; for which reason they must be regarded as rolled rock fragments.

As regards this last proof, it is of no value. I need only refer to the quartzite nodules in our Silurian stage Dd 1, which show precisely the same conditions, but of which it is known that they contain precisely the same fossils as the shales in which they lie, and where, therefore, there is no room for any doubt that both are contemporaneous, and that the nodules cannot possibly have been transported. Here in Bohemia also, minute nodules which bear on their outside fragments of rolled-up *trilobites* or similar organic remains, are found here and there with the other quartzite nodules. They would certainly be regarded as rolled pebbles if they did occur together with other fossils, and contain the same species. This is manifestly an example of imperfect formation of nodules.

The apparently rolled specimens of *conularia* may probably be explained in this way; but on this point I cannot express a positive opinion, as I have not seen the specimens examined by Wynne.

H. Warth sent me lately such an apparently rolled specimen of a *conularia,* which

[1] And pebbles, as described by Warth and Oldham.—W. K.

at the first glance looks certainly very much as if it had been rolled. On closer examination, however, various doubts arise.

In the first place, the size of the specimen, which measures 60 millimetres in length, and 20 millimetres in width at the upper end, but is only 11 millimetres thick. When such a thin elongated body of soft sandstone is exposed to such rough treatment as it must necessarily have undergone when moved along with the conglomerate masses, it is certainly very astonishing that it was not broken into smaller fragments. Then, two of its sides and one edge had been preserved almost intact, although covered with the most delicate sculpturing. Now, an angle is certainly one of the most prominent parts of the shell, and must, when rolling takes place, be first worn off. Of the well-preserved sides, the broader one certainly is concave, and might in consequence have escaped the effects of being rolled, but the other is, in consequence of a peculiar deformity of the specimen, much bellied out. Yet here also the most delicate sculpturing is preserved. I must here remark that the specimen sent to me by Warth is quite enclosed by the matrix, a coarse conglomerate sandstone, and that thus the objection that the piece was perhaps derived from a larger rolled fragment whereby the well-preserved sides being enclosed in the fragment were protected from the wear and tear of rolling, falls to the ground entirely.

Thus in this case also it appears more probable on closer study, that the peculiar preservation of the specimen was due rather to incomplete nodule-formation than to rolling. If the specimen had really been transported and embedded for a second time, it cannot have been brought more than a couple of thousand paces, otherwise the preservation of the sculpturing in particular parts would be utterly inexplicable.

Distinct proof of the "washed up" character of the nodules appears to me not to have been brought forward in Wynne's and Oldham's statements. That would only have been accomplished if they had found fossils of more recent age mixed with older ones. Violently though Oldham defends his views, he cannot produce such evidence.

For all that, I certainly do not assert that the possiblity of the washed up nature of the nodules is absolutely excluded, as I have not been able to revisit the localities since the discovery of the nodules; but a probability of that origin does not appear.

Even if they were washed up, they can only have been derived from a bed differing but little in age from their present site: nor can their original home be far removed from the place where they are now found. A proof of this is the completeness (? restrictedness[1]) of the fauna which they include, and which points to a common site and common origin. But such completeness can only be preserved when the bed which encloses the specimens has been but lately formed (and thus more recent formations could not have been affected by denudation), and when the specimens were only transported a short distance.

If we look around among the formations of the Salt-Range to see from which the nodules might possibly have been derived, if derived they were; we see that it is the magnesian sandstone alone with the Neobolus beds which could have yielded such

[1] Translator, R. B. F.

specimens. But if this be the case, and the nodules emanate from the magnesian sandstone, then this formation must advance upward suddenly into age of the Coal-measures, though they have hitherto been regarded by me as lower Carboniferous.

Shall this be the revision that my views on the Salt-Range are to undergo, as was hinted by Medlicott? Fresh facts were lately collected by Dr. Warth, which threw much new light on the whole question.

In the Nilawan, Warth found the *Conularia* nodules in boulder beds, which appear to follow immediately above the Neobolus beds, and which certainly lie at the base of the speckled sandstone. Here there is now no doubt possible that the *conularia* nodules are older than the *Fusulina* beds which occur in the immediate vicinity of the place of discovery.

There is yet something to be said about the age of the boulder bed. It was regarded by Wynne as Cretaceous, as he united it with the overlying *Cardita beaumonti* beds, which may probably be regarded as uppermost cretaceous, or as an equivalent of the Lamarie group or of the Liburnian stage.

R. D. Oldham insisted most strongly on the cretaceous age of the boulder bed, and maintains that it is unconformable to the underlying beds. Of such an unconformability neither Mr. Wynne nor I myself have seen anything. On the contrary, I have measured sections in which a perfect transition from the underlying beds of the salt crystal zone to the boulder beds could be traced, which was effected by an alternation of green and red sandstones and shales.

But in this respect also there is no reason for being compelled to unite the boulder beds with the upper instead of the lower beds. That such a boulder bed should not always lie as regularly on its soft foundation as is the rule with other formations is in the nature of things. But then such a deposit came to pass under quite unusual circumstances.

In these boulder beds of the olive series [1] their glacial origin is as distinctly expressed as it can possibly be wished.

The boulders and shingle consist most largely of red porphyry, and innumerable specimens show distinct grindings and scratchings. Very many are ground on different sides—a proof that they were at various times impacted in the ice-mass in different positions, while it was still moving. I give herewith illustrations (Plate I.) of two such pebbles, the larger consisting of porphyry, the smaller of a blackish-grey aphanitic rock, and of which the larger is polished on the back and front sides, the smaller on three contiguous sides. The direction of the scratches is different on each polished surface, but scratches often occur on the same surface running in directions crossing each other.

If we review all that has been said up to the present with regard to the boulder beds of the olive series, we shall arrive at the following conclusion:—

(1) The boulder beds appear in the olive series just where it is in contact with [2] the speckled sandstone; while further to the west they are only found in the speckled sandstone in which they occur frequently.

[1] "Olive series" might here be better read "Eastern Salt-Range."—W. K.

[2] ? For "is in contact with," one might here read "passes longitudinally into" or "replaced by."—W. K.

(2) The speckled sandstone can, from its position below the Permian limestones and from the fossil contents of its uppermost beds, be regarded as certainly an equivalent of the uppermost section of the coal-measures.

(3) In the boulder beds of the olive series are nodules, in which, out of 11 species of fossils contained in them, 5 can be identified with species from the Australian coal-measures, and one identifiable with a species from the speckled sandstones.

(4) These *conularia* nodules which occur in the boulder beds of the olive series were lately also discovered in boulder beds in the Nilawan, which certainly lie below the *Fusulina* beds.

As all these conclusions point with great certainty in the same direction, it is difficult not to assume that the boulder beds of the olive series are to be regarded as a partial equivalent of the speckled sandstone, and are approximately of the same geological age as the boulder beds which are met with so largely developed at the base of the Permian limestone.

Hereby we have gained for the Salt-Range a great uniform glacial horizon, which is of very special importance for a right understanding of the great questions which have to be solved here.

It is true that quite lately voices have been heard giving expression to the opposite view; and R. D. Oldham asserts, in a paper in the *Geological Magazine*, that not less than four distinct horizons exist. Unfortunately no new facts have been adduced, and so Oldham's view cannot indeed bring us to give up our own well-weighed view. Such acceptations of the case always go back to Croll's theory that the glacial periods on the earth were as common and as cheap as blackberries—a theory which is in no way supported by the geological facts observed in general. The view that all the glacial formations in the Salt-Range should be reckoned to one and the same group, in no way strains the observations made by Wynne or myself, and can therefore pass as the right one till striking proofs to the contrary are brought forward. I shall have an opportunity further on of returning to the statements about the existence of numerous glacial horizons one above the other in one and the same region.

Other statements made by Oldham in the same paper deserve fuller mention, as they add fresh tracts of glacial formation to those already known in India, and at the same time give information as to whence the glacial gravels of the Salt-Range were probably derived.

In the great Indian desert which stretches from the Arvali range to the Indus, Oldham found, near to the town of Pokran, a land surface consisting of porphyry and syenite which is completely covered with scratches and striations. On this surface lies an extremely tenacious glacial mass, which Oldham claims as Till or Moraine profonde, while in the neighbourhood bedded glacial formations, manifestly of marine origin, occur widely distributed. In the Moraine profonde are only gravels of porphyry and syenite; in the marine formations on the contrary chiefly gneisses and granites which emanate from the Arvali range. Oldham believes, then, that the glacial gravels of the Salt-Range also came from the south, partly from the porphyritic continent, partly from the Arvali Mountains. Oldham assumes also for these formations the age of the Tálchirs.

In a former paper I observed already that I regarded the glacial formations of

the Salt-Range as marine throughout; but I believe not only that great glaciers descended from the Arvalis to the sea, as is assumed by Oldham, and there broke up into icebergs, but much more that the great river, the probable existence of whose mouth in the eastern Salt-Range I mentioned above, carried down to the sea vast floating masses of ice.

However all this may have been arranged, it retires completely into the background in comparison with the great general questions which have yet to be solved here.

The most important of these is the question as to the age of the glacial beds. We have established for the glacial deposits in Australia and Africa that they rest on lower carboniferous formations, and in Australia they contain a marine fauna which points to the age of upper coal-measures. This is opposed by the accompanying plant-remains which are regarded as mesozoic.

We have now, however, become acquainted with glacial deposits which underlie Permian limestones, and actually contain indications of the Australian coal-measure fauna which there lies in glacial beds. According, therefore, to all the laws of synchronism there can be no great doubt that the glacial formations of the Salt-Range are to be regarded as approximately contemporaneous with those of Australia, in which the same fauna occurs. Thus, then, the geological age of the glacial period under consideratton would seem to be altogether settled.

In Australia we have unquestionably lower Carboniferous deposits, Culm measures as their foundation: in the Salt-Range we have beds of undoubted Permian age overlying them directly. Thus nothing remains for us but to assume that the glacial events which we have been discussing took place at a time when elsewhere the upper coal-measures were being formed. The conclusion of the phytopalæontologists, which was referred to above, that in Australia the plants must be the determinants, and that the palæozoic animal types must there have lived on into the mesozoic times indicated by the plant-remains, has thus become quite untenable, and we know now for certain that in Australia, Africa and India, a flora of mesozoic type appears already at the time of the coal-measures. But this is a result of the very widest range, that includes within itself a multitude of further conclusions.

First of all let it be pointed out that the new flora appears elsewere with glacial formations, which is a clear proof that it could bear low temperature and was at the least capable of resisting night frosts. In Australia, as in Africa, this new company of plants dispossesses a series of true carboniferous plant types, as the *Calamites* and *Lepidodendra;* and the gap between the older and newer flora is so great that hardly a single genus is common to both. Under these circumstances, it is quite allowable to assume that the first distinctly palæozoic flora met its end through the advancing cold which the commencement of the glacial period diffused over the great southern continent. What else should have brought about this destruction, since at the same time on other parts of the earth's surface, where equally clear traces of the advent of severe cold are not to be traced, this same flora was at its highest development, and the formation of the coal-measures went on undisturbedly? We have therefore gained a measure for the temperature conditions to which the plant families unite their existence. The palæozic floras, consisting mostly of delicate organisms, were evidently unable to endure lower temperatures, and were bound

to perish as soon as more frequent and more severe frosts commenced. The younger flora on the contrary consisting of mesozoic types evidently contained organisms, which being stronger could resist the lower temperature, and were thus capable of accommodating themselves to more varied conditions of life.

A further inference arises necessarily out of the above, namely, that the younger flora, consisting of mesozoic plant types, was developed autochthonously in the great Africo-Indo-Australian continent; for we find in no country on earth the smallest tittle of evidence that will allow us to conclude that mesozoic plant types had developed anywhere in periods preceding the formation of the coal-measures, and had spread themselves by migration over the southern continent.

A *per contra* assumption immediately suggests itself: that the mesozoic floras of Europe which all show a great typical resemblance, are to be regarded as descendants of the palæozoic flora, which came to be developed on the southern continent during the coal-measure period.

The chief point, however, is always the proof of a glacial period which appeared on the southern continent during the coal-measure epoch, for all the other conclusions are based on this one fundamental fact. But this fact can no longer be doubted since so many observers in many quarters have, quite independently of each other, arrived at the unanimous result that the formations in question came to pass under the influence of ice. Only the settling the age of the formations was doubtful, but this can now be carried out with great certainty.

The glacial formations of this period are spread over an immense area of the earth's surface. They begin in about 40° south latitude and stretch away to about 35° north latitude, and in lougitude from about 35° east of Ferro to 170° east, an area including more than a quarter of the earth's surface, and in extent and size not much inferior to that affected by the most intense action of the quarternary glacial epoch. But while during the quarternary glacial period the northern hemisphere suffered chiefly, and comparatively small extensions pushed down alongside the Andes and through New Zealand into the southern hemisphere, the chief episodes of the Carboniferous glacial period took place in the southern hemisphere, with the glacial deposits on the Afghan-Persia frontier which up to 35° north latitude are but of small extent.[1] All this is obviously correct only in its most general features. Very much is yet required to give us a clear picture of all the conditions, and many further studies will be necessary to complete the sketch here attempted. We ourselves must let our eyes travel still further, and first of all submit the Europe of that time to closer consideration.

V.—EUROPE.

Glacial formations have repeatedly been thought to have been discovered in deposits which precede the quarternary period more or less. We will here disregard Croll's statements, for he thought he could point out numerous glacial formations in every system, for these statements can hardly be accepted as made in earnest. Far more prudently does James Geikie express himself in his classical work, "The Great Ice Age;" for to him the glacial origin of certain beds appears

[1] According to Griesbach's data. Rec. Geol. Surv. Ind., Vol. XIX, p. 57.

to be made out in two cases only. The conglomerates at the base of the Carboniferous in the south of Scotland, and the Permian boulder beds described by Ramsay, appear to him to be certainly glacial.

Unfortunately I could learn nothing in detail from the existing literature about the glacial horizon in the lower Carboniferous of Scotland (as to which it is really doubtful whether it should not be classed as Upper Devonian). I succeeded, indeed with great trouble, in procuring the descriptive text to the geological map, but could find no fuller information in it. Indeed, in England itself the view that these formations are glacial seems to have been given up again more or less. Archibald Geikie in his *Text-book of Geology* lays no great stress on these statements: and lately at a meeting of the Geological Society of London, striated pebbles derived from these beds were shown in order to prove how such scratched gravels could be produced in a secondary way by the sliding of the beds.

It is quite different with regard to the glacial horizon in the Permians which is by all authorities unanimously regarded as unquestionably glacial. I shall later on have an opportunity of inquiring more closely as to this Permian glacial horizon, but for the present we will confine ourselves to the Carboniferous proper. The glacial horizon above referred to at the base of the Scotch Carboniferous appears to be at the very least doubtful.

Only a year after Ramsay had shown the glacial nature of the Permian breccias in England, Godwin Austen[1] mentioned masses of rock out of the conglomerates underlying the coal-measures in France, which masses were of far too great dimensions to have been carried to the sites they now occupy by any other agency than that of floating ice. Although the blocks are described as more or less angular, such a fact, in the absence of other parallel facts, such as polished and striated gravels, hardly suffices to stamp such formations as certainly glacial. The formations may appear to some extent suspicious, but it is hardly possible to base further conclusions on such data, especially when they have been observed only singly and not at many places.

The same holds good probably with regard to the rounded rock masses known from Silesian coal-fields and the Ostraver basin, about which so much has been said of late.[2] These rounded masses occur in the coal itself, and are often of considerable weight (one block of granulite weighed 55 kilogrammes). These blocks had evidently fallen into the coal from above while it was still in a soft peaty condition, and it would appear that the distance whence they were borne must have been a considerable one. It is therefore all the more difficult to say how the transport may have been effected. It would be most easy to assume that ice had been the agent; but it is dangerous to draw such sweeping conclusions from such isolated facts, as other possibilities cannot be absolutely excluded. Various writers have already pointed out that trees can remove rock masses, entangled in their roots, over great distances, and that perhaps some such cause might be assumed to have operated in the cases in the coal-measures. It must certainly be borne in mind that the trees of those days were only occasionally possessed of a plexus of roots in which rock-masses could fix themselves; but on the other hand, the carrying power of those spongy

[1] Quart. Jour. Geol. Soc., Vol. XII, p. 58.

[2] See Stur., Jahrbuch d, K. K Reichsanstalt, 1835, Vol. XXXV, p. 627.

woods may have been greater than that of the compact woods of the existing trees. In any case, the conditions under which those rock-masses were transported must have been very unusual ones, as indicated by the very rare occurrence of such rounded masses in the coal-measures. Anyhow, the occurrence of those rounded masses does not suffice to demand the assumption of a quasi-glacial period at the time of the formations of those coal-measures in Europe.

If the occurrence of solitary large rock-masses in a bed, or even the presence of great accumulations of boulders, were a sufficient proof of once existing ice-action, then no region could well be richer in old glacial formations than the Gailthal Alps. Gigantic boulder beds occur there at very different horizons (green Carboniferous breccias, Uggowitz breccia, Verrucano conglomerate), and if only the general fashion of the rock is regarded, these formations might decidedly be considered glacial. In no case was I able to demonstrate specially the glacial character of these deposits. In the autumn of last year (1886), I specially visited the carboniferous outcrops of this character in the Nœtschgraben, near Bleiberg, on the occasion of several excursions.

The section of the Nœtschgraben was described by Suess[1] in his accustomed masterly style. The lowest exposed rocks are the Carboniferous limestones and shales which are described by Suess as follows :—"The beds underlying the argillo-micaceous shales have a similar composition, but are coarser. They contain quartz veins of precisely similar character to those in the argillo-micaceous shales. Somewhat deeper down appears a green tufa-like rock in company with another dark-green rock, the so-called diorite of Bleiberg. These two latter appear to be connected by transitions.

"Immediately below these lies in thick beds the light-coloured quartz conglomerate of the coal-measures, just as it appears at Kerschdorf at the base of the argillo-micaceous shales. It is accompanied by beds of sandstone, and sometimes these are underlaid by soft black shales whose surfaces are covered by minute spangles of mica. The thicker lower division of these contains various marine fossils, amongst which small *Producti* and *Fenestella plebeia* are the most common; traces of fern-fronds and *Calamites* are mixed up with them. Below these follow some beds of black carboniferous limestone full of *Productus giganteus* and *Poteriocrinus* and stems of *Cyathophyllum*. These are accompanied by a very hard dark-green breccia. Once more follows black shale and again black limestone with *Productus giganteus* and *Poteriocrinus*. These are underlaid in uninterrupted southerly dip by a yet greater mass of those green diorite rocks which were mentioned at the boundary against the argillo-micaceous shale, and with these reappears the dark breccia which acquires a very remarkable appearance, especially where its blackish-green matrix encloses numerous pieces of white granular limestone. Below the American smelting furnace a new bed of black limestone cropping out from below the above contains innumerable huge shells of *Productus* with *crinoidal* stems and *Cyathophyllum*, and is traversed by red threads of gypsum."

It is the dark-green breccias which appear as true boulder beds, and to which my observations have special reference.

[1] Suess, on the equivalents of the "Rothliegende" in the Southern Alps. Sitzungsbericht Akad. d. W. Vienna, 1868; Vol. LVII, pt. I.

These boulder beds are apparently, but somewhat irregularly, intercalated between the beds with *Productus giganteus*, and which have yielded the fauna described by M. de Koninck. The fossiliferous beds become equally irregular in the neighbourhood of the boulder accumulations, are much bent and seem often to have slid together. The boulder heaps themselves frequently show no bedding of any kind, consist mainly of boulders lying together in wild confusion, and often attaining nearly to the size of a cottage, but are otherwise very varied in size, and show as matrix a fine green sandy material (perhaps Diorite tufa?) that appears mixed with more or less coarse sand and gravel. The boulders themselves consist mostly of green, more or less, aphanitic rocks; but other rocks are not rare. They are never perfectly angular, but mostly half-rounded, and perfectly rolled pieces are also not wanting. The individual accumulations of boulders appear not to extend far horizontally. Despite very close searching I could not find a trace of a polished and scratched pebble, and it thus becomes very problematic whether one is dealing at all with a glacial formation. To me the idea that these boulder heaps came to pass by the co-operation of two other factors, appears much more probable; namely, surf and torrent actions. The torrents even to-day remove the same boulders from the beds and carry them away. The beds in the Nötschgraben were doubtless formed in a shallow very near the coast, and thus both factors could exert influence on the formation of the accumulations. The colossal power surf can display I was able to study during a whole winter on the coast of the Bay of Biscay, where rock masses from 2 to 3 feet in diameter in each direction were dashed by the surf waves against the coast with such fury that the groaning of the rock-masses actually overpowered the thundering of the surf.

From this example it becomes clear how careful we should be not to pronounce any boulder bed to be glacial, unless on the one hand polished and scratched pebbles allow of a sure recognition of the glacial origin, and on the other hand, parallel facts permit of the idea of a radical change of climate.

Formations appearing on the most varied horizons in one and the same neighbourhood, which are all declared to be glacial, must from the outset arouse a certain suspicion, and the greater number of statements concerning glacial deposits at different levels in the palæozoic, mesozoic and tertiary epochs, might in the course of time come to have reference only to such totally non-glacial accumulations; or there might be errors in the determination of the ages of the beds, so that when really glacial formations occur they may be referable to but one or to very few horizons.

As I write this, an essay by Dr. Warth, which appeared in the second part of the Records of the Geological Survey of India for 1887, has come to hand, and brings the definitive proof that the four glacial horizons which R. D. Oldham maintained are all to be referred to one single level. The same thing will probably happen to the numerous glacial horizons which have been thought to be demonstrable in the Himalayas. On the one hand, they will probably prove to be mere boulder beds; on the other they will perhaps be reducible to one horizon that will approximate to the horizon of the Salt-Range.

Let us return to Europe, after this digression. We have seen that in the palæozoic formations of Europe there are no absolutely undoubted glacial formations except

in the Permian, but these stand above all doubt. The Permian glacial beds of England were described by Ramsay in a masterly way. They occur in the midland counties, and extend thence over very considerable areas and frequently attain to a thickness of several hundred feet. The blocks are either angular or half-rounded, and often from 3 to 4 feet in diameter. The surface of the greater number of them is smoothed, very many are perfectly polished and bear fine scratchings, which are either all parallel, or belong to different systems crossing each other at various angles. These boulders lie in a red marl and consist nearly all of Cambrian quartzite, of various Silurian rocks and of others of the upper Caradoc, and all must have been carried a distance of at least 20 to 40 English miles.

What place these breccias hold in the Pemian stratigraphical sequence is a little difficult to determine. Underlying them are sandstones and red marls which have yielded *Lepidodendra, Calamites* and (?)*Strophalosia*, and which in their turn rest unconformably on the beds of the upper Carboniferous. The breccias are certainly of marine origin, and belong either to the middle division, or the lower section of the upper division of the Permian. Similar breccias have been pointed out in Ireland and Scotland.

We must thus assume, for a great part of the British Islands at least, at the time of the Middle or Upper Permians, glacial conditions under which the breccias in question were formed. Ramsay, it is true, believes that many also of the "Rothliegende" breccias on the Continent are of glacial origin, but nothing more has been made known about this. Here, however, another fact of great interest has to be taken into consideration; the fact, namely, that in all Europe the transition from the palæozoic to the mesozoic type of the floras, and the dying out of the greater part of the palœozoic plant types, occurs in the middle of the Permian epoch, and is thus again coincident in time with the glacial phenomena described from England. We see thus that in Europe also the thorough change of the flora goes hand in hand with the change in the climatic conditions.

From North America also boulder beds of similar age are cited, but it is not decided positively whether they are really glacial or not. It appears certain however, that at the time of deposition of the Permians a great part of the northern hemisphere was visited by a great depression of temperature. What had happened to the southern hemisphere, already in the upper coal-measure period, only befel the northern hemisphere in Permian times. In each case, however, the thorough change in the temperature conditions is also mainfested in the thorough change of the flora; and by the conditions obtaining in Europe we are led to the same conclusion as we expressed above with reference to the facts observed in the southern continent, that the carboniferous plant types must have been very delicate in their nature and unable to withstand severe frosts.

The Permian cold period in Europe does not, however, seem to have been limited to the northern hemisphere. If we turn to the tabular statament on page iii we see that in the Hawksbury beds in Australia, glacial conditions occur again. These beds should very probably be considered equivalents of our Permian; and thus we should have to note in Australia also a return of cold in Permian times. But here the cold has not acted so effectually; it met with a vegetable community which could endure it, and had previously in part experienced something of the kind, and in consequence we do not see any thorough change of the flora.

In India, traces of the younger carboniferous glacial period seem to be wanting. In the Salt-Range, the older very thick glacial deposits are overlaid by beds with *Fusulina longissima*, *Möll.*, and some other species, and these are followed by the rich Permian fauna described by me. This fauna is by no means an autochthonous one, for it consists of a community of organisms thrown together like dice in a variety of ways.

The greater part of the fauna emanates from the east from China, which had already in the upper Coal-measure period been colonized from America, as is clearly taught by the Lo Ping fauna described by Kayser. A colonization at such an immense distance can only take place under specially favourable circumstances and with the assistance of marine currents. It was these probably which made the climate of China so much milder that the formation of the coal-measures could continue uninterruptedly, while in the neighbouring India great ice-masses were being heaped up. These ocean currents extended in the Permian time as far as the Indian coast of the great southern continent, and by bringing warm waters with them caused there the rich development of organic life with which I became acquainted in the Productus limestone. From this source spring also the majority of the species of the Indian Permian. Another, but smaller number of them, indicates a connection with the carboniferous fauna of Australia. According to the observations of R. D. Oldham, the latter is embedded in the glacial deposits, and may well therefore be considered as a cold-water fauna. If regarded from this point of view; it is explicable why so few types of this fauna, of which indications occur in the glacial beds of the Salt-Range, have survived into the Permian deposits. A third almost invisible fraction of the fauna points to relations with the north (the lands of the Caucasus). But the richer the Permian fauna enclosed in the Productus limestone appears, the more remarkable does it seem that this fauna appears to be suddenly cut off without any transition forms, as soon as the first deposits of the *Ceratite* beds, that is to say, the lowest Trias, appear. This sudden disappearance of the palæozoic animal types in India brings us to another question that has yet to be discussed,—whether the great depression of temperature, which was followed by the above described glacial phenomena, and which showed as its immediate result the extinction of the palæozoic plant types, had also similar influence on the marine faunas, and caused the reduction of the palæozoic animal type to a small residue.

If we study the effect of the cold of the quarternary glacial period on the marine faunas, we see that an extinction of the types is not caused immediately, but that only a horizontal displacement of the faunas sets in, and they thus accommodate themselves in this way to the conditions of temperature.

So, also, in that long past time to which the above described glacial formations belong, the approaching cold will from the first have had that effect, and the several faunas will, from the first, have sought the places in which the conditions of temperature agreed with the conditions of life essential to them. But when in addition to the greatly lowered temperature another distribution of the great continental land-masses takes place, which is followed by a totally different distribution of the ocean currents, then a state of things will appear at many points of the earth's surface which offers no longer the life conditions necessary for a community of marine organisms accustomed to a high-water temperature, and they will have to perish wholesale,

so that only a small nnmber will be able to save themselves and reach a fresh period.

Such a case doubtless occurred in the Salt-Range, while, at the time of the second carboniferous cold period, warm currents flowing here from the east favoured a rich life; but this current was at the Permian period suddenly diverted and replaced by a cold current from the far north.

That this was really the case is proved by the enclosed fossils; for, with the lower beds appear suddenly Siberian cephalapoda types (*Siberites*, &c.) in great numbers. This marine current continued throughout the Triassic and Jurassic periods, and caused a deep descent to the southward of the boundaries of the Boreal marine province. For the Jurassic system, this descent was long since demonstrated by Neumayr.

Thus it appears that the possibility is not barred that the great revolution which occurred also in the fauna of the seas at the end of the palæozoic period, may be referred back, in part directly, in part indirectly, to the great depression of temperature which at the end of the palæozoic time appears to have spread itself over the whole earth, South America excepted.

As far as I know, South America is at present the only continental mass in which glacial formations have not been shown, either in the upper Carboniferous or the Permian.

The presence of a mild climate in this quarter is proven by the existence of coal-measures with genuine carboniferous plants in Brazil.

South America seems to have played a similar part during the carboniferous glacial period to Western North America in the time of the quarternary ice cap; where, as shown by Campbell, glacier traces are very sparingly present, and are restricted to the higher-lying parts of the country.

I have thus striven to demonstrate a glacial period which appeared with great intensity in the upper Carboniferous period on a continent the greatest part of which lay south of the equator; but which later in the Permian period extended itself over the greatest part of the globe. However many ice-made formations in earlier and later times have been mentioned in geological literature; at no time can such deposits be shown in such wide extension as in the Carboniferous[1] and the quarternary periods.

As far as our knowledge now extends, there appear thus to have been two great periods of cold which our earth has passed through up to the present; and of these the second seems to have been pretty nearly the counterpart of the first.

From my deductions, however, it becomes abundantly clear that in the earlier, as in the later, times, the distribution of the plant types on the surface of the earth was dependent on climatic conditions, so that plant remains can only be used as leading fossils under certain restrictions and precautions.

To enter upon the causes of the great depression of temperature in the Carboniferous period, is not in the very least my intention. Endless studies will yet have to be made ere any degree of clearness will be attained to in this respect. I would

[1] When I speak here of the carboniferous in general, I reckon the Permian as a sub-division of the Carboniferous. I do not at all believe that the Permian can maintain itself as an independent system.

only mention that the explanation indicated by R. D. Oldham in the Geological Magazine for 1886, and before that in the Journal of the Asiatic Society of Bengal, appears to me quite insufficient, as the conditions are certainly much more complicated than pre-supposed by that attempt at explanation.

The Sequence *and* correlation *of the* Pre-Tertiary Sedimentary formations *of the* Simla Region *of the* Lower Himalayas, *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.*

Since the publication of the *Manual of the Geology of India*, there has been no general review of our knowledge of the geology of the Himalayas, yet so great has been the progress made since then, that it becomes daily more necessary that the many isolated accounts of different portions of the Himalayas should be amalgamated, so far as is possible, and a starting point for further work obtained.

As long as the survey of the Himalayas is in active progress, the individual workers are naturally loth to publish anything which, having the appearance of finality, would perhaps be superseded by the next season's work: but as my own work in the Himalayas, which has been interrupted for some time, may be suspended owing to more pressing demands made on the Geological Survey, this will give an opportunity for publishing a summary of the present state of our knowledge of the region with which I am personally acquainted.

Owing to the many interruptions of my work in the Himalayas, it is impossible for me to give a detailed account of the geology of the Simla Region, and I shall consequently confine myself to giving an account of the sequence which will be useful as indicating systems which have been identified in the region under consideration, of which equivalents may be looked for in other neighbouring regions.

"Central gneiss" series.

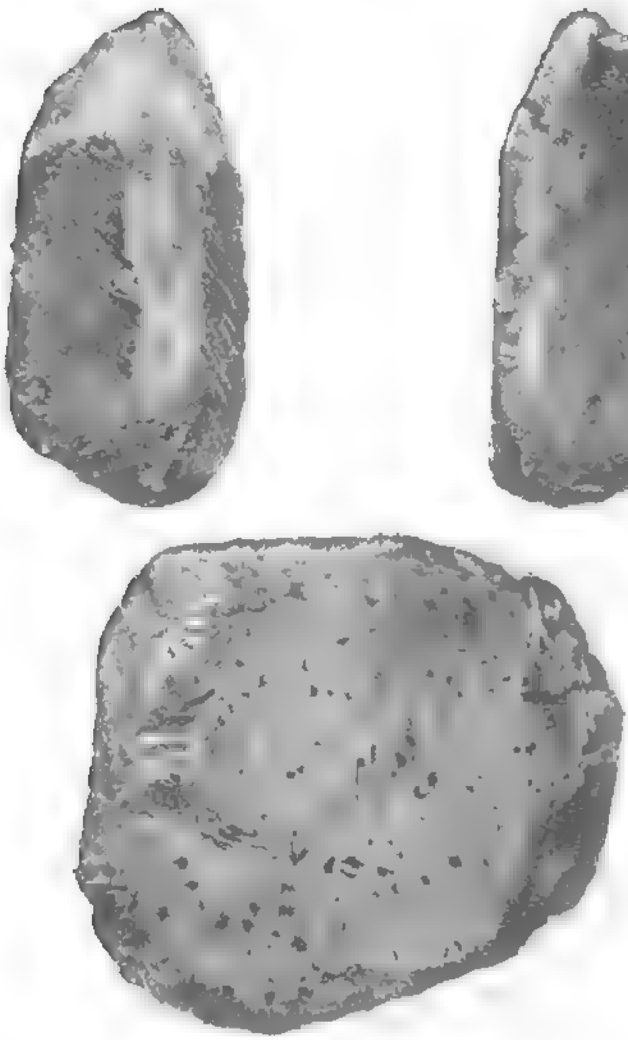
Within the limits of the Simla Region, by which is here meant that part of the Lower Himalayas which lies west of the Jumna river, the oldest series of rocks consists of bedded gneiss. The occurrence of gneiss in the Himalayas was noticed by the earliest observers, but it was first separated as a distinct system by Dr. Stoliczka, who named the gneiss, seen by him on the Babeh pass, the "Central gneiss"[1] from an idea that it formed the original axis or core on either side of which the sedimentary beds of the Himalayas were deposited.

Though the hypothesis on which this idea depended is no longer tenable, and the name, in so far as it implies a theory, inappropriate, yet as this theory has been abandoned by geologists the old name may safely be maintained as preferable to Laurentian or Archæan, both of which imply an hypothesis there is no means of verifying.

Babeh pass section.

The Babeh pass section does not strictly belong to the Lower Himalaya but is so close to the ill-defined boundary of this region that it will be considered here. On the ascent from the Sutlej river

[1] Mem. Geol. Surv. Ind., V, pt. i.



Polished and scratched pebbles from the Boulder bed, Chel Hill, Salt Range

at Wangtu bridge an apparently continuous sequence of not less than 11,000 feet of gneiss is seen dipping at high angles to north-north-east. The rock varies in texture and composition a few thin bands of mica schist being seen, but for the most part it is a massive, often granitoid, gneiss; in some of the beds the foliation is absent or obscure and these generally contain porphyritic crystals of orthoclase, twinned on the Carlsbad type. The foliation is parallel to the bedding planes and the successive layers, varying in thickness from a few inches to a few feet, differ from each other in texture and mineral composition; showing that, whether metamorphosed from ordinary sediment or not, the rock was originally formed by some process analogous to, if not identical with, ordinary sedimentation.

Exposure at head of Pábar valley.

Beds belonging presumably to the same system, though differing somewhat in mineral character are exposed in the upper part of the Pábar valley in Bissáhir.[1] Here there is a much larger proportion of very slightly felspathic mica schists and quartzites, some of the latter being perfectly free from felspar and showing their detrital origin very distinctly; on the other hand some of the beds are almost pure orthoclase. None of the beds of gneiss are as highly metamorphosed as the generality of those on the Babeh pass section, but *augen* gneiss is abundant; in some of the beds lenticular masses of felspar over an inch thick and about three in length are scattered through the rock, the internal structure being in all cases that of a crystal twinned along a plane passing through the edge of the lens and lying parallel with the planes of foliation.

Possibly two series.

In spite of the differences between the gneiss of the Pábar valley and that of the Babeh pass I have thought it best, in the absence of any proof to the contrary, to class them together; the occurrence of *augen* gneiss in both and the fact that the most common accessory minerals are schorl and garnet in both cases, is to a certain, though slight, extent, confirmatory of this conclusion.

The central gneiss appears to occupy but a very small area within the Simla Region as here defined but it attains a great development in the Central Himalayas.

The Jaonsár system.

Next following the central gneiss comes what I shall call the Jaonsár system. This was first identified by me in the district of Jaonsár; it was named the Chakrata series,[2] and divided into an upper and a lower group. But subsequent examination of the same system where it is more satisfactorily exposed, west of the Tons, has led me to the conclusion that it should be divided into three divisions, the lowest of which was, through a mistaken correlation, erroneously classed with the uppermost.

Lower Jaonsár subdivision.

Of these three divisions the lowest consists of a great thickness of grey slates containing, towards the upper limit, a band of blue limestone about 300 feet thick. They have not been fully examined and it is not even certain whether they really belong to this system or no.

Jaonsár quartzites.

The middle division of the Jaonsár system is characterized by the prevalence of red quartzites and slates It forms the hill or which the sanitarium of Chakrata is built and there consists of purplish red slates and quartzites, the latter not infrequently mottled with white.

[1] For description see Rec. Geol. Surv. Ind., XX, 160.
[2] Rec. Geol. Surv. Ind., XVI, 93.

The same purple quartzites are found in the Naira[1] and Bangál valleys of Eastern Sirmur, and at the head of the Pábar valley the gneiss series is unconformably overlaid by purple quartzites and slates, above which come hornblende schists, probably representing the volcanic beds of the upper group.

Unconformable to central gneiss.

The beds of the upper Jaonsár group are exposed in the northern part of Jaonsár Báwar, but their relations to the quartzites are better shewn in the Bangál valley in Eastern Sirmur, on the southern side of which the red quartzites and slates of the lower group are overlaid by about 200 feet of dark-grey felsitic trap covered by as much more of mixed trap and volcanic ash. This does not, however, exhibit the whole thickness of the volcanics, as their upper part is cut off by an unconformity.[2]

Upper Jaonsár.

The volcanic beds of Northern Jaonsár differ from these in some respects; lava flows are rarer while ashes, interstratified and mixed with sub-aqueous sediment are abundant, moreover a band of limestone, some 300 feet in thickness is interstratified in the series.[3]

This difference is due to a difference in the mode of origin; while the volcanics of Jaonsár were certainly deposited under water those of the Bangál valley were of sub-aerial origin. At one place a layer of pebbles, some of lava but mostly of vein quartz, was found interstratified with the volcanics.[4] The presence of lava pebbles would not prove more than the contemporary existence of a volcanic island, but the quartz pebbles point to the proximity of an area of non-volcanic rocks, whose shores must have bounded the sea area of the Jaonsár period.

An old land area.

On the northern side of the Bangál valley these volcanic beds are overlaid by a great thickness of sub-schistose slate, but whether it belongs properly to the Jaonsár system or a newer one is not known.[5]

Possible newer group.

Before leaving this system I must mention that a conglomeratic bed, similar to that of the Blaini group, to be described further on, has been recorded in two distinct localities, and in both cases low down in the section. The most westerly of these is on the north side of the Bangál valley. Here at the eastern boundary of the Jaonsár system, where it is faulted against the Deoban limestone, there occurs a bed of semi-schistose red quartzose slate, through which are scattered rounded boulders of hard crystalline quartzite. The position of this bed in the section is a little doubtful as the rock was not seen *in situ* but the position in which the detached fragments were found and the similarity between the matrix and some of the beds of the Lower Jaonsár group, alike indicate that it occurs low down in that system of rocks. It is important to note that the bed cannot be of volcanic origin, as is proved by the rounded, water-worn form of the boulders; and that it is not associated with any volcanic beds, being separated by between 2,000 and 3,000 feet of sedimentary beds from the upper Chakrata traps.[6]

Boulder-bearing beds.

[1] Neweli of Atlas of India.
[2] Rec. Geol. Surv. Ind., XX, 157.
[3] *Ibid.* XVI, 193 (1883).
[4] *Ibid.* XX, 157.
[5] R. D. Oldham, MSS. Report.
[6] R. D. Oldham, Rec. Geol. Surv. Ind., XX, 157 (1887), and MSS. Report.

A somewhat similar bed occurs in Northern Jaonsár, where it has been recorded as Blaini. Here the matrix is quartzite and the included fragments are angular, this combined with the presence of volcanic beds among the quartzites with which it is interbedded renders it impossible to declare that the rock is not of volcanic origin.[1] This hypothesis does not, however, seem to me to fit the case, and it is certainly equally probable that it is of the same age and origin as the Bangál rock. What may have been the origin of the latter I shall not at present discuss.

Deoban system.

Above the Jaonsár volcanics there is, in Northern Jaonsár, a great development of limestone which forms nearly all the higher parts of the group of mountains running north from Deoban. This limestone was at one time regarded as the equivalent of that seen on the Krol mountain, south of Simla; but was named Deoban limestone[2] by me in 1883 in consequence of a doubt as to the correctness of this identification. Subsequent investigation has shown that the two limestones are distinct, so the provisional name may stand. The unconformity of this system to the Jaonsár beds is very plainly seen in Northern Jaonsár and is especially well-marked in the valley of the Dháragadh where the occurrence of a band of limestone among the beds of the Jaonsár system serves as a horizon to mark the oblique truncation of the beds of the older series by the contact surface between them and the Deoban limestone.

The Deoban system as seen in Jaonsár consists of a pale grey, bedded limestone, with a varying proportion of dolomitic beds and intercalated slates. The limestone is frequently mephitic, in places contains cherty concretions, and is occasionally oolitic. A speckled limestone shewing black specks on a white ground is common and some of the beds exhibit a peculiar pseudo-organic structure which gives them the appearance of being composed of a mass of closely chambered shells; curiously enough these apparent fossils are generally imbedded in a matrix which weathers brown, while they retain their blue-grey colour.[3] The structure is possibly of organic origin, but if so, it is impossible to guess even the family of the animal that produced it, and if of purely concretionary origin it is strange that it should be found over so large an area. I have found it in Sirmur, west and south of the Giri, and a precisely similar structure was described, and illustrated, by Dr. McClelland, in the "transition" limestone of Kumaon.[4]

This system is not known with certainty to occur away from the Deoban exposure, but it is almost certain that some of the exposures of limestone south-east of the Chor should be ascribed to it, while the great limestone of the Shali peak, north-east of Simla, probably belongs to the same system.

The carbonaceous system.

Following on the Deoban there comes a system which I find some difficulty in treating satisfactorily. It probably occupies a more extensive area in the north-western termination of the Lower Himalayas than any other system of beds, but all the

[1] Rec. Geol. Surv. Ind., XVI, 193, (1883).

[2] Rec. Geol. Surv. Ind., XVI, 195.

[3] Loc. cit.

[4] Jour. As. Soc. Beng., III, 628, plate XXXV, fig. 4 (1834), see also Geol. Mag., 3rd Decade V, 255 (1888), where a similar structure from the limestone of Kulu is described, and considered as of organic origin.

sections examined as yet shew individual peculiarities, and as it is impossible to say where the system is best exposed I am driven to take a descriptive name from the slates impregnated with carbonaceous matter which characterize its upper portion, and I shall speak of it as the carbonaceous system.

Sub-divisions, Simla slates.

On the Simla section the lowest group seen consists of a great thickness of grey slates, gritty slates and quartzites, being the Infra-Blaini or Simla slates of Mr. Medlicott.[1] It is not absolutely certain whether these slates do or do not belong to the carbonaceous system, but in the neighbourhood of Simla there is no indication of an unconformity and for the present it is best to class them here.

Blaini group.

Following on the Simla slates comes a very peculiar group of beds, originally described by Mr. Medlicott, under the name of Blaini, as follows:—[2]"The principal rock of this little group is a pure limestone, very dense, ometimes compact sometimes sub-crystalline; its commonest colour is pale pink, but often blue and greenish-yellow; it occurs in thin, well-defined layers, but these are often agglomerated together into one mass, the beds shewing only as bands in this mass.* * * It has a constant companion, more peculiar than itself, and the two combined furnish an unmistakable clue. This other rock is a kind of conglomerate. It occurs, I believe, below the limestone, though in the many inverted contortions it often appears above. The base of this conglomerate is a fine, gritty slate, of a dull green or blue colour, in fact altogether like the thin-bedded rocks in the midst of which it occurs. Through this base pebbles of quartz are thinly scattered, seldom larger than a hen's egg. These pebbles are sometimes so scarce as to pass unnoticed without special search. In most places sub-angular fragments of a *slate* rock are the prevailing foreign elements in the conglomerate, which thus assumes a very brecciated aspect."

With regard to this description I must remark that there seem to me some objections to the application of the word "conglomerate" to such a rock as is described. We require some term that indicates the occurrence of pebbles scattered through, and separated from each other by, a slate matrix, a structure which involves some special mode of formation and deserves a special name. But it is necessary to choose one that does not involve a theory, and perhaps the best name that can be applied is "boulder slate," on the analogy of "boulder clay," meaning thereby a slate containing scattered fragments of foreign rock, irrespective of the actual size of these fragments. An objection to the term is, of course, that indirectly it implies a theory, the term boulder clay having become almost synonymous with glacial; this objection may be held to be of less weight, as the theory implied is the only one that satisfactorily accounts for the known facts and, in any case, there is no essential or direct connection between the term used to describe the effect and the assumed cause. I shall therefore use the term "boulder slate" as meaning a slate which encloses boulders or pebbles of some older rock, and without reference to the theoretical origin of the rock.

The Blaini group, in the form originally described, has a tolerably extensive dis-

[1] Mem. Geol. Surv. Ind., III, pt. ii, p. 33.

[2] *Op cit.* p. 30. The name was originally spelt Blini, but the more correct spelling Blaini is now generally adopted.

ribution, being found even east of Mussoorie, but as a rule the boulder slates are nore extensively developed, and the limestone, even in the neighbourhood of Simla, s by no means a constant member.[1]

Carbonaceous division.

Above the Blaini group, and intimately associated with it comes the series of beds from which I have derived the name of the system. They were originally described by Mr. Medlicott as "Infra-Krol" from the fact of their occurrence underneath the Krol imestone on the Krol mountain. The series is there only partly exposed and this as vell the suggestion of association with the Krol limestone might be held to necessi-ate supersession of the name, but it has held its own for 30 years in the Survey publications and it will be best to retain it, but in a more extended sense as including he "Krol quartzite." On the Simla hill the series consists of two bands of slates nd limestones more or less impregnated with carbonaceous matter, separated by bout 1,000 feet of schistose quartzites and garnetiferous mica schist. These last, which have been described as "Boileauganj quartzites," most probably represent he "Krol quartzite" of Mr. Medlicott—a term I shall discard as the beds lescribed under it appear to belong to the carbonaceous system rather than to the Krol limestone.

Volcanic beds: carbonaceous division.

In the Simla section there is no trace of volcanic activity if we except some hornblende schists occupying the summits of Prospect and Jako hills at Simla, but elsewhere, in Jubal and Bisahir,[2] volcanic beds are everywhere found in the upper part of the eries. They consist of ash beds, more or less mixed with ordinary sediment of letrital origin, and lava flows; the latter have not been examined in detail but appear o be for the most part basalts, more or less altered by subsequent change, frequent-y amygdaloidal but as often exhibiting no indications of a scoriaceous structure. n the recorded sections they are always interstratified with sediments and the shes are more or less impure, showing that they were formed by submarine erup-ions, though the actual vents may in some or all cases have been raised above the ea-level.

It may be noted that the distinctness of these volcanics from those of the Jaonsár eries is marked not only by their position in the sequence, but by the much more asic type of the rocks they are composed of.

The different sections do not agree as to the position of the volcanic beds in he series. At Simla the hornblendic rocks are in the upper carbonaceous band. n the Sutlej valley they appear to occur both above and below as well as interstrati-ed with white quartzites like those above which they occur on the Lambatách ridge. n the Deora valley of Jubal their position is doubtful and on the eastern flank of the Chor they seem to occur near the top of the lower carbonaceous band. The general onclusion that may be arrived at is that the volcanic beds do not belong to any xed horizon but occur with greater or less vertical extent throughout the upper art of the Infra-Krol series, and always, so far as is known, well separated from the oulder slates of the Blaini group.

[1] See Rec. Geol. Surv. Ind. X p. 204 *et. seq.*, XX, p. 158.

[2] Rec. Geol. Surv. Ind. XX, 159; the volcanic beds of the Sutlej valley described by Col McMahon also belong to this division. See Rec. Geol. Surv. Ind., XIX, 65, *et seq.*

Carbonaceous series of the Lambatách ridge.—On the Lambatách ridge, which rises north of the Tons, immediately above its junction with the Pábar, and in the north of Jaonsár-Báwar the carbonaceous series assumes a peculiar form. In the valley of the Koti gádh (Kunjado river) there is a series of coarse-grained foliated arkose rocks. Owing to the presence of large fragments of orthoclase and to the subsequent foliation of the rock it is difficult and often impossible to distinguish a hand specimen from some forms of the intrusive gneissose granite, but in the field there is little difficulty in telling the two rocks apart, not only does the arkose decompose more readily than the granite, but on looking over a weathered surface it is not difficult to find small pebbles. At a little distance, however, the huge rounded masses of the arkose are easily mistaken for an outcrop of granite.

Above this coarse-grained arkose there come foliated beds containing granules of felspar, which pass upwards into a coarse-grained felspathic quartzite or grit full of small granules of undecomposed felspar. In this rock pebbles and boulders ranging to over a foot in diameter occur, not heaped together, but scattered through the matrix of grit. The whole of the beds up to this are characterized by containing numerous granules of blue quartz. Above the conglomeratic grits come fine grained quartzites which extend across the Tons and were described by me as the Báwar quartzites;[1] they are semi-transparent where undecomposed but weather opaque white and ultimately into a very fine, sharp, white sand, owing to the decomposition of the felspathic cement; above these come volcanic beds and above them carbonaceous slates and limestones.

The conglomeratic grits above mentioned are, to say the least, not incompatible with a glacial origin; while it is difficult to understand how either gneiss or granite could have disintegrated without decomposition of its constituent minerals except under a severe climate. This combination of beds, indicating a period of exceptionally cold climate, overlaid by carbonaceous slates and limestones associated with volcanic beds seems to join these beds to the carbonaceous series, while, as an additional proof, schistose beds, characterized by the presence of granules of blue quartz are largely developed in connection with carbonaceous slates in the hills west of the Pábar river.

Mandháli beds of Jaonsár.

There remains for consideration a group or series of beds distinguished by me in 1883[2] as the Mandháli series and classed as distinct from the Blaini group. The group, as I now prefer to call it, is of the most protean character, consisting of quartzites, slates, limestones, conglomerates and boulder beds in most variable proportions and interstratified in the most extraordinary manner; it being not uncommon to find slates or even limestone interbedded with coarse grits or conglomerates This variability appears to be due to the fact that it has been deposited in close proximity to land, and always contains a large proportion of debris derived from the older rocks of the neighbourhood. Thus in Northern Jaonsár and Báwar, where it rests on the Deoban limestone fragments of that rock are extremely abundant in it and there are several beds of a conglomerate composed exclusively of rounded boulders of the Deoban limestone imbedded in a matrix of the same rock in a finely comminuted

[1] Rec. Geol. Surv. Ind., XVI, 197.
[2] Rec. Geol. Surv. Ind., XVI, 196.

form, while in Southern Jaonsár, where it rests on the quartzites of the Jaonsár series the group consists almost entirely of coarse quartzites and grits.

But the great characteristic of the Mandháli group is the presence of boulder beds of the same type as that of the Blaini group. So great indeed is the similarity that in more than one case an exposure of this group has been described as Blaini.

In Jaonsár the Mandháli group appears to be completely isolated and the rocks occurring next above it removed by denudation,[1] but on the eastern flanks of the Chor mountain at the head of the Minas gadh (Suinj R. of Atlas of India) and east of Chepál in the Jubal State beds shewing the same characteristics as the Mandháli group rest unconformably on a massive limestone, fragments of which they contain. The limestone is similar in character to the Deoban limestone of Jaonsár, with which it is, moreover, continuous at the surface; and the beds overlying it may be taken to represent the Mandháli group of Jaonsár. But these last underlie, apparently with perfect conformity black carbonaceous slates which again underlie a great thickness of quartzites and schists undistinguishable from the Boileaugunj quartzites of Simla.

Identity of Blaini and Mandháli.

This section would seem to indicate the indentity of the Blaini and Mandháli beds, a conclusion further supported by the peculiar and exceptional character of both and the occurrence of recognizable Blaini beds both east and west of Jaonsár, where, with the exception of the Mandháli beds they are unrepresented. If we take the glacial origin of the two as proved, this in itself would establish the contemporaneity of the two groups of beds which outside evidence places between the Deoban and the upper part of the carbonaceous system. The only indication of their separation lies in the fact that when examining Jaonsár in 1882-83 I separated the Mandhális from the Báwar quartzites which are here classed with the carbonaceous system. But the separation was based on the difference in disturbance of the two groups, a difference which subsequent experience has shewn me might well be due to the superior homogeneity and massiveness of the Báwars.

The Krol system.—Above the beds of the carbonaceous series there is, on the Simla section, a limestone series described by Mr. Medlicott as the Krol limestone, owing to its forming the upper part of the mountain of that name rising over the cart-road to Simla. According to him the limestone may be divided into an upper and a lower portion, the distinguishing mark being a greater preponderance of shaly beds in the lower half, though a perfect transition is stated to occur between them.

Like the Deoban the Krol is a blue limestone with frequent concretionary masses of chert. The lithological similarity is so great that they might be and have been taken for the same series, but the superposition of the one and infraposition of the other to the carbonaceous series leaves no room for doubt that they are distinct.

The Krol limestone extends south eastwards from the Krol mountain to the eastern borders of Sirmur, and in Jaonsár there occurs a newer limestone, sometimes resting directly on the Deoban sometimes with the intervention of beds of the Mandháli group, which can hardly but be the Krol.

[1] Rec. Geol. Surv. Ind., XVI, 196.

Mr. Medlicott regarded this limestone as conformable to the underlying beds, but the great variations, in the thickness of the Krol quartzite, as recorded by him, and the total absence of the great thickness of quartzites and upper group of carbonaceous beds seen on adjacent sections, point very strongly to an unconformity. If the upper limestone of Jaonsár is Krol, and it can hardly be anything else, the unconformity is unquestionable for the whole thickness of the carbonaceous series is there wanting.

As yet neither upper nor lower members of this group have been determined, though it is hardly credible that the whole sequence should consist of only a few hundred feet of limestone with shales towards the base.

A sequence of marine beds.

Such is the sequence in the Simla Himalayas as far as it has at present been determined, and throughout this vast thickness of rocks not a single fossil has been found, if we except the peculiar organic-looking structures found in the Deoban limestone, yet there can be little room for doubting that they are principally if not entirely of marine origin. The hypothesis that they may be of fresh water origin has been proposed to account for the absence of fossils, but it has never been strenuously upheld and appears to be inconsistent with the vast thickness of some of the systems or with their uniformity over an area much larger than that described as the Simla region of the Himalayas.

Only two attempts have been made to correlate the rocks of other parts of the Himalayas with those of the Simla region, one by Dr. Stoliczka in 1865, and the other by Mr. Lydekker in 1883; but since both were ignorant of any more extended sequence than that contained in Mr. Medlicott's memoir, it is not necessary to refer to them in detail.

Correlation dependent on physical characters.

As no fossils have been found in any of the rocks of the Simla region, it will be necessary to depend on the physical characters of some of the groups. Their mere lithological similarity is well known to be valueless for the identification of rock groups unless applied within a very limited area and over very short gaps. A sequence of groups each shewing certain lithological characters is more important, and where a similar sequence of similar rocks is found greater weight attaches to it than to the mere lithological similarities of single groups. But even this would fail when applied over such distances as we have to deal with.

The reason for this is easy to find, and lies in the fact that conglomerates, sandstones, shales, limestones, and any gradation between them have been forming at every period of the earth's history, since it cooled down sufficiently to allow of life, and that the formation of any particular variety of deposit at any particular place and time depends on the accidents of current, depth, and distance from shore. But the same objection does not apply to those characters which are the result of causes which act intermittently at long-separated periods and independently of the accidents which control the nature of ordinary sediments.

Prominent among such would be the traces of a glacial period which we might expect to find wherever sediment was being formed on the sea bottom.

Of less value would be the occurrence of beds of volcanic origin, for though seldom if ever confined to a single locality, volcanic energy generally begins slowly,

lasts long and is apt to recur in localities not far separated from each other at intervals which, geologically, are not of great duration.

Of similar nature may be the peculiar impregnation with carbonaceous matter seen among the shales of the carbonaceous series, for in other parts of the Himalayas similar beds are found and everywhere, so far as is known, confined to a single group in the sequence.

Carbonaceous system.

Among the many systems in the sequence of the Simla-Himalayas, the carbonaceous system exhibits all three of the special peculiarities noted above and we may consequently expect to recognize it with comparative certainty in other regions where it may exist. Among these that which most naturally comes first is the Kashmir area where the rocks more nearly approach those of the Simla region in character than do those of the Central Himalayas.

In the Cashmere region Mr. Lydekker[1] divided the sequence of pre-tertiary rocks into three systems :—

3.—The Zánskár system.
2.—The Panjál system.
1.—The Metamorphic system.

These three systems are described as not only conformable in themselves but are spoken of as conformable to each other; the metamorphic system is regarded as palæozoic (Cambrian) while the newest beds of the Panjál system are Cretaceous. Such an enormous conformable sequence of rocks, stretching from early palæozoic to latest secondary times, is not only in itself unusual but is directly contrary to what we find to be the case in other parts of the Himalayas; and it becomes necessary, in consequence, to enquire into the grounds it is based upon.

The metamorphic system is regarded as composed of gneiss of two distinct ages, one archæan, the other composed of metamorphosed beds of Panjál age. This is not in itself impossible, for, though the general tendency of modern geologists is to regard a gneiss series as necessarily older than a slate series, it is by no means proved that slates are never metamorphosed into gneiss. But the facts detailed by Mr. Lydekker do not necessitate this conclusion ; he confessedly does not distinguish between the true central gneiss and the gneissose granite, both are indicated by the same colour on the map and described together in the same chapter without being specifically distinguished,[2] and what he has described as partial metamorphism of the Panjál rocks into gneiss seems to be more properly described as intrusions of gneissose granite in the Panjál slates. The error is one which, owing to the tendency of the granite to be intruded in sheets parallel with the bedding and the highly foliated structure it usually assumes under those circumstances, has been fallen into by more than one observer previous to Mr. Lydekker.

"Panjál system."

The Panjál system is used as a generic term for "all the rocks below the Kuling series, and above the metamorphics." As might be expected from this comprehensive definition, the different sections

[1] Mem. Geol. Surv. Ind., XXII, (1883).
[2] Mem. Geol. Surv. Ind., XXII, chap. IX.

described vary widely among themselves. What may be called the type section, that across the Pir Panjál range is described as consisting of—

1. Greenish slates and sandstones with amygdaloidal traps.
2. Black and green slates with thick beds of conglomerate, containing pebbles of quartzite and slate.
3. Whitish quartzites and sandstones.
4. Black schisty slates with pebbles of gneiss and quartzite.[1]

It is further stated that "the resemblance of some of the rocks of No. 2 to the lower division of the Blaini series, both petrologically and stratigraphically, cannot fail to be noticed:"[2]

Panjal traps.

The volcanic beds No. 1 are largely developed in Kashmir and Mr. Lydekker is probably right for the most part in classing them all of one age. The occurrence of volcanic beds at two distinct horizons in the Simla region does not necessitate both of them being represented in Kashmir, and the only indication of two distinct volcanic series that I can find is in the description of the section on the road from Kashmir to the Kishenganga valley over the Tútmári pass where the volcanics are said to occur at a lower horizon than in the Kashmir valley.[3]

In the neighbourhood of the Kashmir valley there is a perfect conformity between these traps of the "Panjal system" and the overlying Kuling series at the base of the "Zánskár system," or to speak more correctly, the volcanic outbursts continued well into the Kuling period.[4]

Kuling series.

The rocks of the Kuling series consist of limestone quartzite and shale or slate, the former appears to be more abundant in the Kashmir valley than elsewhere, while the latter is often impregnated with carbonaceous matter like the slates of the carbonaceous series in the Simla region. It has yielded a series of fossils, limited in number, but still enough to fix its homotaxis with the lower Carboniferous rocks of Europe.

Probable unconformity above the Kuling.

The conformity between the Kuling and supra-Kuling series appears to have been assumed rather than proved; indeed, Mr. Lydekker's description has several passages which point to the opposite conclusion. The supra-Kuling beds are described as resting, at more than one point directly on the Panjal traps without the intervention of the Kuling beds, but in respect to this he says that wherever it occurs he has concluded that "the Kuling series has been included in the trappean rocks and cannot consequently be recognised as a distinct formation."[5] But it is equally open to conclude that it indicates an unconformity, and this conclusion is supported by the fact that both in Spiti and in Hundes an uncomformable break occurs between the Carboniferous and Triassic beds.

Supra-Kuling.

The supra-Kuling beds of Kashmir appear to consist almost entirely of massive limestone and dolomite which have yielded some fossils, for the most part, unfortunately undeterminable specifically

[1] Mem. Geol. Surv. Ind., XXII, 216.

[2] Similar beds occur in an analogous position below the volcanic beds in the Sind valley and on the slopes of the Hóksar range east of the Kashmir valley.

[3] Mem. Geol. Surv. Ind., XXII, 225.

[4] " " " " " 135.

[5] " " " " " 148.

but indicating the triassic age of the lower portion of the series. It is very probable that on more detailed examination this series will have to be split up into more than one and will certainly be sub-divided into groups.

With the third sub-division, or Chikkim series, which is represented only by a couple of isolated patches, we have no present concern.

From the above it appears that Mr. Lydekker's division of the beds above the gneiss, into two systems, is not a natural one and it is extremely probable that a more detailed examination of the country will result in an amplification of the sequence similar to that which has taken place in the Simla-Himalayas.

Carbonaceous system represented.

One point, however, seems clear, that there is in the Kashmir area a conformable series of beds charactized by the occurrence of: (1) boulder-bearing slates of non-volcanic origin, (2) at a higher horizon copious indications of contemporaneous volcanic activity, and (3) the occurrence of beds remarkable for the prevalence of carbonaceous matter. The similarity between the boulder slates and those of the Blaini group in the Simla-Himalayas has been especially remarked, and similar beds are found in the intermediate country of Chamba; while the resemblance between the volcanics of Cashmere, of Chamba, and of the Sutlej valley, the last of which belongs to the carbonaceous series, has been remarked upon by Colonel McMahon.[1]

These coincidences can hardly be all of them fortuitous and the conviction naturally forces itself upon one that the series of rocks referred to above is the equivalent of the carbonaceous series in the Simla-Himalayas; and the conclusion becomes irresistable when we compare the latter with the Kuling series in Spiti.

Kuling series of Spiti.

The series of rocks named Kuling by Dr. Stoliczka[2] is exposed in the only localities that have been visited as yet, at the bottom of a valley: the whole thickness is not seen and they are moreover very much disturbed. The beds, however, consist of quartzites and black carbonaceous slates similar to those of the carbonaceous series, and at two spots in the Spiti valley pebble-bearing slates, precisely similar to those of the Blaini group have been found, one of these being certainly among the Kuling beds. No beds of volcanic origin have been found but this may only be due to the imperfect exposure of the section.

Here, again, the coincidences can hardly be entirely fortuitous and we are justified in accepting Dr. Stoliczka's identification of these beds with the carbonaceous, or as they were then styled Infra-Krol, beds of the Simla area. In a similar manner the Kuling beds of Spiti and Kashmir might be safely correlated on the ground of their physical characters alone; but in this case we have the confirmatory evidence of fossils, four out of the seven species found in Spiti having also been found in the Kuling group in Kashmir.[3]

[1] McMahon. Rec. Geol. Surv. Ind., XVIII., 97, 98, and XIX, 68.

[2] Mem. Geol. Surv. Ind., V, pt. i.

[3] The three localities mentioned in the text probably do not by any means indicate the limits of the area over which the carbonaceous system maintans its uniformity. In the neighbourhoed of Naini Tal carbonaceous slates, conglomeratic slates and volcanic beds, are developed largely, and will probably prove to belong to a single system when fully examined.

Homotaxis of the carbonaceous system.

Having established the presence of beds belonging to the carbonaceous system in Kashmir and Spiti, we may now proceed to the consideration of the homotaxis indicated by the fossils that have been found in these districts.

Classed as lower Carboniferous, but probably newer.

The fauna[1] comprises 46 species in all, of which 17 are also found in the lower Carboniferous of Europe, 12 in the marine Carboniferous beds of Australia, and 16 in the Productus limestone of the Salt-Range. From the above it has been concluded that the genaral homotaxis is with the lower Carboniferous beds of Europe; but there are good reasons for considering the beds as newer than this.

In the first place the relationship of the fauna to that of the Productus limestone is close though not sufficient to establish contemporaneity considering the small intervening distance; moreover, the identities being among the more characteristically palæozoic forms of the Productus limestone fauna is compatible with an earlier date of formation. On the other hand, the Productus limestone of the Salt-Range is, like the Kuling group of Kashmir, underlaid by a conformable sequence of beds at the base of which occur boulder shales of generally acknowledged glacial origin. These doubtless are the equivalents of the boulder-bearing slates of Kashmir and Simla and of contemporaneous origin with the latter. In view of this, and of the known variations in the marine fauna of neighbouring localities due to variations of environment, I think far greater weight should be attached to the similarity than to the differences between the two faunas and they may consequently be regarded as homotaxial, if not of contemporaneous origin. In this case the age should be determined by the more extensive fauna, that of the Productus limestone, which has been regarded by Dr. Waagen as of Permian age, a date which, in view of the presence of so typically mesozoic forms as *Ammonites*, we may safely regard as the oldest admissible date.

Further evidence pointing to the same conclusion is the occurrence in the glacial beds below the Productus limestone of fossiliferous pebbles[2] of derivative origin which have yielded a limited fauna closely allied, so far as it goes to that of the marine Carboniferous beds of Australia. There can be little doubt that the beds, from which these fossiliferous pebbles are derived, are the equivalent of the Tálchir group in the Peninsular area, and I have elesewhere given my reasons for regarding the latter as the equivalent of the marine Carboniferous beds of Australia, and not as the Salt Range pebbles would indicate of later age. The Tálchirs, I need hardly add, are now generally regarded as of uppermost palæozoic, probably Permian age.

From the above it will be seen that the fauna of the Kuling group can be made to indicate a homotaxis anywhere between the lower Carboniferous and Permian horizons of Europe. This is a good instance of the limits of error necessarily attaching to the palæontological method when applied over long distances; but enables us to arrive at the conclusion that the carbonaceous system of the Hima-

[1] See Lydekker. *Mem. Geol. Surv. Ind.*, XXII, 158.

[2] The strictly pebbly condition is open to question, see R. G. S. of I., XX, 118, and Dr. Waagen's Essay on "The Carboniferous Glacial Period," in present number, p. 118, which should be read in connection with the whole of this paragraph.—*Ed.*

ıyas was deposited during the latter end of the palæozoic period, and corresponds to art, if not the whole, of the Carboniferous and Permian eras.

The Jaonsár system.

The only other system which I can correlate with any degree of certainty is the Jaonsár system, the lower group of which is probably represented by the middle division of the Babeh series of Dr. toliczka. The lithological resemblance of the groups is most striking and though o volcanic beds are seen in the Babeh pass section they are described by Dr. toliczka as occurring in Lower Spiti.

quivalent to Vindhyan.

In the Peninsular area it may be represented by the Vindhyan system, the rocks of which would, if more indurated and disturbed, resemble those of the Jaonsár system. A further piece of evidence ıough not at present of great value, is the occurrence of beds of possibly glacial rigin at the base of the Jaonsár system and the occurrence of beds containing ırge boulders imbedded in a fine-grained matrix among the Vindhyan beds east of ıe Aravalis, and the occurrence of similar beds at the base of a series of rocks, ccurring west of the Aravalis, which have been, with little or no hesitation, classed s Vindhyan by every observer who has examined them.

Of Silurian age.

This correlation would give the Jaonsár and Vindhyan systems an age corresponding at the latest to part of the Silurian system of Europe,—a correlation, so far as the Vindhyans are concerned, ı accordance with that adopted by the authors of the Manual, though at variance ·ith that suggested by Mr. Griesbach.[1] This latter, however, is even more conjecural in its basis than that which I have offered, and, moreover, does not appear to llow sufficient time for the enormous unconformity between the Vindhyans and the ondwanas of the Peninsula.

Other systems.

As regards the remaining systems of the Lower Himalayan sequence, it is impossible to do more than guess at their ages. The central gneiss is presumably of "Archæan" age, for the Deoban imestone I can find no equivalent among the fossiliferous beds of the Central Iimalayas, while the Krol limestone is probably represented by part, which part annot be determined, of the limestones which extend from Lower Trias to Lias in piti and Kashmir.

General conclusions.

The general conclusion we may arrive at is that throughout the whole of the Palæozoic and Mesozoic periods the area under consideration has been alternately land and sea, and that throughout his long period there appears to have been but little disturbance of the beds, in onsequence of which there is a general parallelism of dip and unconformity can, s a rule, only be determined by overlap.

[1] Rec. Geol. Surv. Ind., XIII, 88.

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MAPS.

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July 16th, 1888.

28

Government of India Central Printing Office.—No. 5 D. G. Survey.—28-8-88.—620.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1888. [November.

Notes on Indian Fossil Vertebrates, *by* R. LYDEKKER, B.A., F.G.S.

1. THE ULNA OF *Hyænarctos.*

Among a small collection of bones obtained by Mr. R. D. Oldham in the Siwaliks of Kasamúri Rao, Sahāranpur district, and lately sent to me by the Director of the Survey, the only specimen of any interest is (No. H $\frac{47}{8}$) the nearly entire right ulna of one of the species of *Hyænarctos.* Of this bone the proximal extremity is represented in the accompanying woodcut (fig. 1). In regard to the generic reference, it is quite clear that this specimen does not belong to the *Felidæ;* and the only other known Siwalik carnivore of sufficient size to which it could belong is *Hyænarctos.* The specimen agrees, moreover, with the imperfect ulna in the British Museum noticed in the 'Palæontologia Indica,' ser. 10, vol. II, p. 225, which was probably associated with the type skull of *H. sivalensis;* and since it closely resembles the corresponding bone of *Amphicyon,* its reference to *Hyænarctos* may be considered certain.

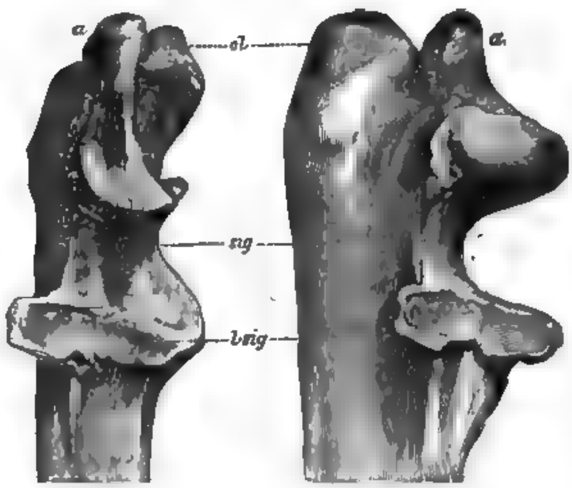

Fig. 1. Palmar and preaxial aspects of the proximal extremity of the right ulna of *Hyænarctos;* from the Siwaliks of the Sahāranpur district: ½ nat. size. *ol.,* olecranon; *a,* anterior tuberosity of do.; *sig.,* greater sigmoid cavity; *l. sig.,* lesser sigmoid cavity for head of radius.

In the above-mentioned ulna the proximal extremity is wanting; and since there is

great variation in this part among the different genera of Urso-Canoids, some important conclusions may be drawn therefrom as to the affinities of *Hyænarctos*. It will be observed from the figure that the olecranon is well developed, ascending a considerable distance above the proximal portion of the greater sigmoid cavity for the articulation of the humerus, and possessing a strongly-marked anterior tuberosity. The lesser sigmoid cavity is deeply concave, and indicates free supination of the manus. Compared with the ulna of *Amphicyon* figured by Dr. Filhol in the 'Ann. Sci. Géol.,' vol. X, pl. XIV, fig. 3, the resemblance is so close that in the absence of other evidence the two specimens might well be referred to the same genus. In the ulna of *Canis* the well-developed olecranon is retained, but the lesser sigmoid cavity becomes much flatter and less well defined in correlation with the greatly diminished power of supination of the manus. Turning, however, to the ulna of *Ursus* (fig. 2), we find a wide difference from our specimen, owing to the abortion of the olecranon and the almost total disappearance of its anterior tuberosity. A very similar condition of the olecranon obtains in the Primates, and is, I presume, connected with the power of straightening the fore arm on the upper arm.

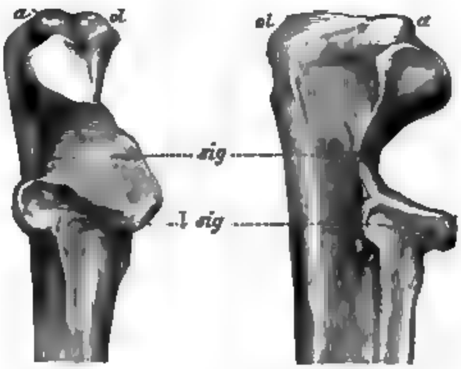

Fig. 2. Palmar and preaxial aspects of the proximal extremity of the right ulna of *Ursus arctos*: ½ nat. size. Letters, as in fig. 1.

In my description of the skull of *Hyænarctos* in the 'Palæontologia Indica' already cited, the conclusion was reached that this genus might be regarded as connecting *Amphicyon* with *Ursus* through the intervention of the American *Arctotherium*. This conclusion receives support from the present specimen, which (as is the case with the carnassial teeth) is nearer to the corresponding element of *Amphicyon* than to that of *Ursus;* and I conclude that the humerus was in all probability furnished with an epicondylar foramen, as in the former genus. In *Arctotherium*, which displays a dentition much more like that of *Ursus*, the olecranon has become aborted after the Ursine type.

Finally, I may observe that on page 239 of the above-quoted memoir I expressed an opinion that the dentition of *Hyænarctos* was more specialized than that of the Bears. This opinion I now withdraw, and, in accordance with the views of Professor Flower, I look upon the Bears as the most specialized members of this branch of the Urso-Canoid stock; which have, however, to suit their fissorial and scansorial habits, retained the primitive pentedactylate and plantigrade feet.

2. *Massospondylus*, FROM THE KAROO AND GONDWANA SYSTEMS.

In my memoir on the 'Reptilia and Amphibia of the Maleri and Denwa Groups' published in the 'Palæontologia Indica,' ser. 4, vol. i, pt. 5 (1885), I described (pp. 26–29) and figured certain Reptilian remains from the Maleri beds which I regarded

as Dinosaurian, and placed in the neighbourhood of the English Triassic genus *Thecodontosaurus;* following the lead of Professor Huxley in classing the latter with *Scelidosaurus* and its allies. I thought it, however, advisable to refrain from giving a generic name. These remains comprise one extremity of the centrum of a dorsal or lumbar vertebra (pl. V, fig. 4), a caudal vertebra (*ibid.*, fig. 7), some phalangeals (pl. IV, figs. 7, 8), and teeth (pl. VI, fig. 10, and woodcut fig. 1, p. 29). The vertebræ are amphicœlous, with long, laterally-compressed centra, having oval terminal faces, and the upper surface deeply excavated by the base of the neural canal. The phalangeals resemble those of the Ornithopoda and Theropoda; while the teeth come nearest to those of the European *Thecodontosaurus* and the North American Triassic *Anchisaurus* (*Amphisaurus*); these two genera being placed by Professor Marsh in a single family of the *Theropoda* under the name of *Anchisauridæ*.

During a recent visit to the Museum of the Royal College of Surgeons I was struck with the resemblance to the above-mentioned specimens presented by a series of Reptilian bones collected many years ago from the Karoo system near the town of Harrismith, in the Drakenberg range, Basutoland. These specimens are catalogued by Sir R. Owen in the 'Catalogue of Fossil Reptilia,' pp. 97, 99 (1854), under the names of *Massospondylus* and *Pachyspondylus;* caudal vertebræ being taken as the types of the two genera. The bones are coated with a hard ferruginous matrix, and are indistinguishable as to mineralogical condition from Maleri specimens.

It will be unnecessary on this occasion to discuss the question whether there are really two genera among these South African specimens; and it will be convenient to refer to the dorsal vertebræ and limb-bones under the name of *Massospondylus*, since there is at least an equal probability of their belonging to this genus rather than to *Pachyspondylus*. The specimens comprise, in addition to the caudals, several centra of trunk vertebræ, an ilium, and numerous phalangeals of the manus and pes. In the original notice it was stated that some of these remains showed Dinosaurian affinities, but their ordinal position was left an open question.

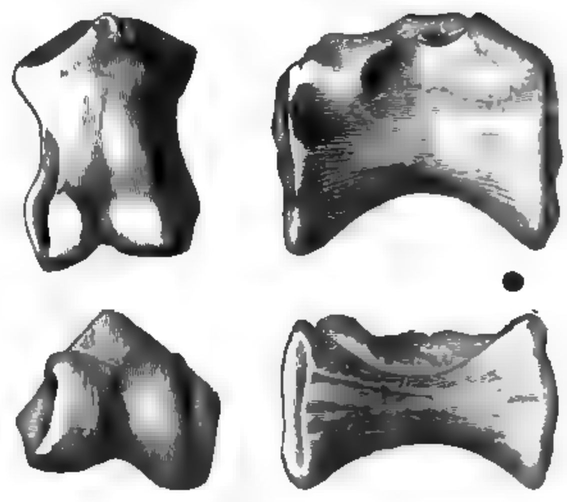

Fig. 3. Dorsal and distal aspects of a phalangeal of the manus, nat. size; and lateral and hœmal aspects of the centrum of a trunk vertebra, ½ nat. size, of *Massospondylus carinatus;* from the Karoo system of Basutoland.

With our present knowledge of the structure of the Dinosauria it is at once apparent that these African bones are referable not only to that order but to the sub-order Theropoda. Thus the ilium, which belongs to a small individual, is of the general type of that of *Megalosaurus*, although presenting well-marked generic differences. The

characteristic sharply-curved terminal phalangeals of the manus are also decisive as to the subordinal position. In the trunk vertebræ, of which one specimen (No. 336) is represented in the accompanying woodcut, the centrum is much constricted laterally and excavated inferiorly, with oval and amphicœlous terminal faces, after the manner of the dorsals of *Megalosaurus*. Certainty is added to this resemblance by the presence of a fusiform median cavity in the centrum, as is demonstrated by a transverse fracture now cemented together. One of the second or third phalangeals of the manus (No. 380) is shewn by the side of the vertebra in fig. 3.

The special interest of these specimens lies, however, in their close resemblance to the above-mentioned Dinosaurian bones from Maleri. The vertebra figured in the accompanying woodcut, except for its smaller size, cannot indeed be distinguished from the Maleri specimen shewn in pl. V, fig. 4 of my memoir; while the figured African phalangeal of the manus agrees in all respects with the larger Indian phalangeal of the pes represented in pl. IV, fig. 8. It is true, indeed, that these resemblances are insufficient to indicate with absolute certainty the generic identity of the Indian with the African form, yet when we bear in mind the occurrence of generically identical Dicynodonts in the Gondwana and Karoo systems, the extraordinary similarity to one another presented by those two series of deposits, and the absolute identity in the mineral condition of the African and Indian specimens under consideration, I venture to think that we may be justified in referring the latter to the African genus. Accepting this reference, important evidence is afforded by the Maleri teeth as to the relationship of *Massospondylus* with the *Anchisauridæ*, to which family it may, I think, be pretty safely referred. I am not, indeed, in a position to say whether the Old World genus is really distinct from *Anchisaurus*; but if the latter is unknown in Europe its appearance in India would be very unlikely. The original notice of *Massospondylus carinatus* is too incomplete to allow of the name being regarded as more than a manuscript one; and, if such a course be permissible, I would suggest that it might date from the present description, with the figured specimens as the types.

The matrix of the African specimens of *Massospondylus* being different from that in which the African Dicynodonts are found may be taken as fair evidence of a distinct geological horizon; and since the occurrence of Dicynodonts in the Panchet stage of the Gondwanas indicates the probability of these beds being the equivalents of those which yield the same family in Africa, it is probable that the Harrismith beds yielding *Massospondylus* are the equivalents of the Maleri stage, which is considerably higher than the Panchets.

In conclusion, I may express my thanks to Professor Stewart, Conservator of the Royal College of Surgeons, for permission to describe the African specimens.

Some Notes on the Geology *of the* North-West Himalayas; *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.*

SPITI.

The observations on which the following remarks are based were made during a tour, through Ladak and Kashmir, undertaken with a view to determining how far the discrepancies between the sequence of beds in Kashmir, as described by Mr. Lydekker, and that of the Simla region was real. As the country traversed has, with a small exception, already been examined cursorily by previous observers, I shall only notice those points on which I find it necessary to differ from or amplify opinions already recorded.

The first exposure of gneissose granite seen was on the road between Narkanda and Kotgarh at about one mile before the road to Kotgarh branches off from the old Hindustan and Thibet road. This exposure is apparently a continuation of the lower of the two exposures on the Hattu ridge, recorded by Colonel McMahon, but, owing to the density of the forest, the two could not be traced into continuity. Colonel McMahon has expressed an opinion, based on the microscopical characters of the rock, that these exposures must be regarded as metamorphic gneiss, not granite. I find myself unable to agree with this opinion, for not only do both bands occur among schists and bacillary quartzites undistinguishable from those of the Boileauganj Hill and like them associated with black carbonaceous slates, but in the exposure on the summit of Hattu I saw several well-defined crystals of orthoclase lying with their longer axes more or less transverse to the planes of foliation. Mineralogically the rock is a gneiss, and in the lower exposure the porphyritic crystals of felspar have lost their crystalline outline and form mere lenticular eyes, so that both macroscopically and microscopically the rock might well pass for gneiss did not its association preclude the idea.

But this loss of the characteristics of an intrusive rock is not nearly so marked as in an exposure on the old road from Kotgarh down to the Sutlej. Here, above the village of Shaot,[1] there is what looks like highly-foliated mica schist, with little or no quartz but occasional specks of felspar. For the most part the rock is very soft, but there are occasional harder bands which, owing to a larger proportion of felspar and quartz, have resisted decomposition. On breaking open a block of the micaceous rock the felspar is seen to be in larger proportion than appears on the weathered surface, as each speck is but the termination of a rod of felspathic material devoid of definite crystalline structure. The rock occurs among carbonaceous slates and quartzites of the type of the Infra Krol groups of Mr Medlicott, and can hardly be ascribed to a metamorphism of part of these beds *in situ*, while the drawing out of the felspathic material into strings is probably due to fluxion while the rock was in a plastic condition. If this conclusion be correct the rock is an extremely impure representative of the gneissose granite, several other exposures of which, all highly micaceous, though not so much so as this one, occur lower down the same spur.

[1] Situated on the spur between Súlan (Súilán) and Kété (Rita).

Along the Sutlej valley exposures of gneissose granite are common and have already been recorded by Colonel McMahon; they are all shewn to be granite by the occasional occurrence of definite crystals of orthoclase lying more or less transverse to the foliation planes. These crystals become more numerous and conspicuous towards the east; in other words the further the intrusions are traced from their eastern source the more do the originally well-formed orthoclase crystals lose their crystalline form and become degraded into rounded lumps of felspar.

Rocks of the Sutlej Valley.—With the exception of the gneissose granite, some true gneiss seen on the last two marches and the diorite intrusions described by Colonel McMahon,[1] the rocks between Kotgarh and the Wangtu bridge are of volcanic origin, carbonaceous slates, white quartzites similar to those of Bawar and other less characteristic beds belonging to the same series which I have proposed to call Carbonaceous. Two interpretations of the section have been given on different occasions by Colonel McMahon, but beyond expressing an opinion that both require extensive modification I shall add nothing to what has been written above. All conjectural interpretations of Himalayan sections, not based on extended survey, are in the last degree hazardous, especially where, as in the present case, the section is carried almost along the strike of the beds.

Central Gneiss of Wangar Valley.—I have already incidentally mentioned the occurrence of true gneiss south of the Sutlej valley, but the series is much better exposed on the ascent from Wangtu bridge to the Sutlej valley. At the bridge itself oligoclase granite is *in situ*, as has been abundantly described by previous observers, but on the ascent it soon gives way to gneiss. I have nothing here to add to the late Dr. Stoliczka's description but to say that it is most indubitably a gneiss series and as distinct as can be from the intrusive gneissose granite. Occasionally specimens are so highly granitoid that the foliation has disappeared, but the occurrence of well-defined beds, arranged parallel to each other and differing in lithological structure and mineralogical composition, shew that the series must have originated by sedimentation or some analogous process. The junction of the gneiss and slate series of the Babeh pass is marked by an intrusion of the gneissose granite; and nothing could be more distinct than the porphyritic granite devoid of stratification, with its defined crystals of felspar lying without any definite orientation, and its numerous inclusions, whether of foreign rock or formed by greater local concentration of the micaceous element on the one hand, and the distinctly stratified gneiss, often granitic, not infrequently porphyritic but with the porphyritic felspar, whether crystalline or in the form of lenticular eyes, lying parallel with the foliation, planes on the other.

Babeh Pass and Spiti section.—I have little to add to Dr. Stoliczka's description of this, and nothing to modify except as regards the lower portion.

The lowest beds, or slate group of the Babeh series, contain some bands of carbonaceous slate which render it probable that they may be brought into their present position by disturbance. The upper beds of the series, consisting of red quartzites resemble very strongly the quartzites of Chakrata, even to the occurrence of fragments of serpentinous rock and occasionally a film of serpentine on the bedding planes, as is not uncommon among the 'Lower Chakratas' of N. E. Jaonsar.

[1] Rec. G. S. of I., X, 214, *et seq.*; XII, 65, *et seq.* and 75, *et seq.*

Above these quartzites are some black carbonaceous slates, slightly schistose and shewing a sheen on the foliation surfaces, very common among the 'Infra Krols' of the Simla area. It is not impossible that the upper and lower groups of Stoliczka's Babeh series may be the same, and that instead of a regularly ascending section there is a very much compressed anticlinal. However, beyond the occurrence of black carbonaceous slates there is nothing to support the supposition; I could not recogniz: the slates on either side of the quartzite as belonging to the same group.

The Muth series of Stoliczka resembles nothing I am acquainted with in the Simla area. One thing I feel certain of, that it does not represent the Blaini group of Simla; the conglomerates of the Muth series are perfectly ordinary conglomerates and quite different to the very peculiar Blaini rock. According to Dr. Stoliczka there is a transition between the Muth and Babeh series, the purple (red) beds at the base of the former being said to be interbedded with the green and grey slates and quartzite at the top of the former. I do not know how far this statement rests upon a direct observation, or how far it may depend on a distant view of the cliffs overhanging the left bank of the stream.[1] If only the latter, little weight can be attached to the observation, as fallen fragments shew that ther ed colouration of the bands interbedded in the grey beds is superficial, while the colour of the lower group of the Muth series extends through the rock.

The uppermost group of speckled and white quartzites so strongly resembles some of the quartzites of the Carboniferous series of Kashmir, and in a less degree of the Carbonaceous series of the Simla area, that one may be allowed to doubt whether they should not be ascribed to the Kuling series. This would make the Muth series Carboniferous, though the obscure fossils it has yielded were regarded by Dr. Stoliczka as Silurian. As none of these were specifically determinable, perhaps too great weight should not be allowed to this opinion.

The Kuling or Carboniferous rocks are not well exposed in Spiti; its apparently capricious appearance and relations to the other sedimentary groups support the opinion expressed by Dr. Stoliczka, that there was an unconformable break at the close of the Carboniferous period. The lithological resemblance of the beds to those of the carbonaceous series of the Simla area is striking, and at two spots in the Spiti valley a rock occurs which resembles in structure the Blaini conglomeratic slate. The first or easternmost of these is associated with beds believed by Colonel McMahon[2] to belong to the Carboniferous or Kuling group: in this I agree with him though no great certainty attaches to the identification. But in the case of the second exposure there can be no doubt whatever that the beds among which it occurs are of Kuling age.

The similarity of the rocks of the Kuling and Carbonaceous series of itself suggested to Dr. Stoliczka the probability of their being the same, and when we find beds, like the conglomeratic and carbonaceous slates, both of which, and especially the former, point to special and unusual conditions of deposition, common to the two, this suggestion acquires a degree of probability which closely approaches a certainty.

[1] Dr. toliczka's route lay along the right bank.

[2] Rec. G. S. of I., XII, p. 63.

Recent and Glacial Deposits of the Babeh Pass.—One of the most striking features noticeable on this route is the marked absence of distinct traces of glaciers south of the pass and their conspicuousness north of it. The valley of the Wangar is straight and open, and without interlocking spurs—a feature often regarded as characteristic of glacier action. But as the valley has been filled to some hundreds of feet with recent river gravels which have been largely re-excavated by the stream this feature is not conclusive: for once deposition begins to take place in a rocky valley the stream is no longer confined to one channel but is free to wander over the gravelly bottom of the valley and impinge on one spur after the other, gradually cutting away their extremities and so forming a straight and open valley. This may be seen everywhere in the Himalayas where a stream is flowing in a gravelly bottom; often the oldstraight valley with its floor of deposition can be traced, while at a lower level the stream flows in a narrow tortuous channel with interlocking spurs.

The mere openness of the valley is not, therefore, by itself a proof of its having been filled by a glacier. Nor are any moraines seen south of the pass, though there are several landslips which might pass for moraines. The first of these forms a pine-clad barrier stretching across the valley immediately below the summer grazing ground of Muling. In form it resembles a moraine, but it contains no fragments of the slate which forms all the hills at the head of the valley, while immediately above it is a recent landslip repeating its features on a smaller scale. This landslip, which was said to have fallen last year, extended across the river channel and evidently for a time dammed it back as the barrier has been breached, leaving a portion of the landslip separated from its source by the river channel. Although breached it has not been without influence on the river, for above it the spread-out shallow course of the stream and the partially buried trees shew that the gradient has been checked and that deposition is taking place.

Further up-stream there is again what might be mistaken for a moraine were it not that the deposit consists entirely of blocks of porphyritic granite fallen from above; while there is not a single block of the slate which commences a mile higher up and extends to the watershed.

Above Portirang, whence the track strikes up from the valley to cross the Babeh pass, there is another old landslip, and above it a plain of sand and fine gravel which seems to occupy the position of a former lakelet dammed by the landslip.

From Portirang the path ascends a steep slope of débris, and here we first come upon an indubitable moraine, for this slope is that of the moraine of a small glacier which, descending from the pass, rode out into the valley over its own moraine.

North of the pass there is a landslip just above Práda;[1] and at Práda a hummocky grass-clad surface which appears to be a moraine. Lower down, the valley broadens out, and at Baldar there is a perfectly preserved moraine stretching across the valley in a crescent, convex down-stream.

Below Baldar the bottom of the valley is occupied by river deposits of rounded

[1] This is Baldar of the map; Baldar, misprinted Balair in Dr. Stoliczka's memoir, p. 18, is further down, at the junction of the first considerable stream from the east.

gravel, but over these a glacier must have travelled, for less than a mile above Múth there are the remains of an old moraine resting on the river gravels.

We have consequently distinct traces of glaciers having extended on the north side of the pass to a distance of 3,000 feet below and 17 miles from the crest; while on the south side no certain traces can be found more than 1,000 feet below and about ½ mile from the crest.

This difference is paralleled by the present distribution of ice; south of the pass there is said to be a small glacier; I was not able to determine its extent as the whole country was covered with snow, but it cannot extend for more than a ¼ mile. To the north, on the contrary, the descent leads for over 2,000 feet and 2½ miles over the Babeh glacier. The contrast is doubtless due to the fact that the waste is much less on the north than on the south side of the pass; not only from the intensity of the sunshine being less, but to a much larger extent owing to the comparative absence of rain, little of which falls north of the pass, while there is probably a much less proportional difference in the snowfall.

Recent Deposits of the Spiti Valley.—In the valley of the Spiti recent deposits are largely developed and extend high up the N. E. side of the valley. It is noteworthy that the slope of the obscure bedding in some of these shews them to be portions of talus fans which came from the S. W., so that it becomes clear that as the Spiti river excavated its course in the neighbourhood of Dhankar it worked out a channel lying S. W. of its original one.

It is evident from an examination of these deposits that the Spiti river has seen many vicissitudes and has frequently changed from erosion to deposition and *vice versâ*. At one time its valley for many a mile was occupied by a lake whose only vestiges now are whitened cliffs of fine laminated clay which can be seen at intervals from near the bridge at Mani to near Lára, a distance of 9 or 10 miles. The stuff is fine and clayey; on the surface it weathers pale yellowish-white, but inside it is of a grey colour; where not covered by rain-wash it may be seen to be finely stratified; near the sides of the valley strings of angular gravel tail off into it, while everywhere small pebbles are to be found though rarely; in composition it consists largely of finely comminuted limestone, in consequence of which it effervesces freely with acid and a large proportion is dissolved. From these facts it is not difficult to conclude that the stuff is mainly if not entirely glacier-mud which has been deposited in a lake.

LADAK AND KASHMIR.

Gneissose and Granitic Rocks of Rupshu and Ladak.—These have been referred to by both Mr. Lydekker and Dr. Stoliczka, but as neither distinguished between gneiss and granite their descriptions leave much to be desired.

The rocks on the shores of the Tso Morari are not gneiss as marked on Mr. Lydekker's map but slates mostly somewhat schistose and limestones. Among these there is an intrusion of gneissose granite which sends off many veins running through and among the slates; this is the southern of the two exposures of gneiss mentioned by Dr. Stoliczka on p. 127 of his memoir.

North of the Tso Morari the slates &c. are unconformably underlaid by a true gneiss series, distinctly stratified, with the foliation parallel to the stratification, which extends to the southern boundary of the Indus Valley Tertiaries.

The next exposure seen belonged to the Ladak range. This rock I saw on the pass between Maya and Shushul, again on the Chang La and along the north bank of the Indus from Ladak to near Nurla. Everywhere the rock was a syenite, on the Chang La micaceous, shewing no signs of stratification or foliation. Mr. Lydekker has described it to the west of Leh as having a dip to N. E.; all I could detect was a parallel system of joints dipping in that direction, but there was no division of the rock into bands differing from each other in composition. On the contrary it presents all the characters of an igneous rock, meaning thereby a rock which has solidified from a fluid condition. Inclusions of finer-grained rock differing in composition from the main mass are frequent, but besides this there are great variations in the composition of the rock: large masses of highly hornblendic rock ramify through the syenite and intrusions are frequent.

The whole mass so far as its composition goes might be intrusive, but if so the intrusion was of long pre-tertiary date, for the bottom beds of the tertiaries rest on an eroded surface of the syenite, indicating a lapse of time sufficient for the removal of the vast thickness of rock that once overlaid the syenite. Whether the latter is Archæan or no older than the granite intrusions of the outer hills I am unable to say.

The high range south of the Pangong lake, where crossed by the road from Shushal, consists of gneiss with intrusive veins of gneissose granite.

Finally the Tertiaries at Khargil rest on an unfoliated granitic rock containing hornblende, whose relation to the Tertiaries is the same as that of the Ladak range.

The Indus Valley Tertiaries.—As these have already been described by Mr. Lydekker more fully than I could do, I shall confine myself to considering the conclusions that may be drawn from them.

To begin with the serpentine rocks: both Dr. Stoliczka and Mr. Lydekker speak with uncertain voice regarding their mode of origin, but both convey the impression that they form a large intrusive mass, though in both descriptions there are not wanting indications that the authors did not altogether accept this conclusion.

I crossed these rocks once on the section from Puga to Maya and again between Leh and Kashmir. In both cases I found beds of clastic origin, ashes and agglomerates interstratified with traps. To take the first-named section: starting from Puga the first rock seen, after leaving the gneiss, is a serpentinous slate; this is succeeded by a conglomerate or breccia of slate and limestone, the fragments all flattened by pressure and traversed by an imperfect cleavage, and fine-grained laminated beds with fragments of rock included. The matrix of these rocks contains many small fragments of pyroxene. Further on the volcanic facies becomes more marked and we have tuff and ashes with dense pyroxenic traps, all of which have undergone more or less complete serpentinous change.

Where the stream bends to the east the dip of the beds, which had been northwards, changes to south but is very obscure. At the bend of the stream a bed of limestone occurs among the volcanics but is cut up by faults into small patches of a few yards across scattered up and down the hill side in a most perplexing manner, and this intense cutting up of the beds is sufficient to account for the absence of distinct and continuous bedding in the traps.

As to the interpretation of the section, it would at first appear that from Puga to the bend in the stream there was an ascending and below that a descending sec-

tion; the crystalline limestone occupying the centre of a synclinal. But lower down-stream this same limestone occurs on the hills south of the valley above the dense traps, and to judge by the fragments brought down by streams, is overlaid by beds very like those seen in contact with the gneiss.

On the section along the Kashmir road these features are not so well seen, but even there ash-beds can be found among the traps. So there can be but little doubt that we have here a true volcanic series.

I must not be misunderstood to deny the existence of intrusive rocks; I have myself seen these some miles south of Karzók on the Tso Morari and as far north as Shushal. Intrusive rocks doubtless occur among the volcanics,—indeed this is but what might be expected and may doubtless account for the ambiguity in the two published descriptions.

As to the lithology of the beds, beyond what is implied in the above passages, nothing need be added to the descriptions of Dr. Stoliczka, Mr. Lydekker, and later, of Colonel McMahon.

I must next consider the supposed evidences of glacial action exhibited by the lowermost beds in the Indus valley. As described by Mr. Lydekker the sandstones contain boulders of gneiss often several feet in diameter. "Some of the isolated boulders shew the beds of the sandstone bending down below them; and the polishing and smoothing of some of the others seems suggestive of ice action."

So far as my observations go I saw no blocks smoothed and striated in the manner characteristic of glacial action; nor did I see any case of the bedding of the sandstones being bent down under the blocks, though the bedding in their neighbourhood sometimes shewed a disturbance evidently due to eddies caused by the boulder, and except for the size of many of the blocks there is no necessity to invoke glacial action. But among these sandstones there are many thick banks of angular blocks of stone ranging to many feet across and shewing for the most part a sharp angular outline. They must consequently have been derived from the immediate neighbourhood or else transported by some agency—such as floating ice —that would not expose them to abrasion. Now in these banks only a very small proportion of the fragments consists of the syenite of the Ladak range, while the bulk of them are an intensely hard hornstone porphyry which has not been seen by me—or so far as I can find out by any other observer—in the Himalayas. It is precisely similar to the Maláni porphyries of Western Rajputana; and in Srinagur I was shewn some pieces of a similar stone said to have come from Badakshan.

Besides this indication of glacial agency there may be mentioned the presence of undecomposed felspar, doubtless derived from the crystalline rocks of the Ladak range on which the tertiary beds rest, in the sandstones, some of the beds being principally composed of it.

In the Himalayas I have not found the crystalline rocks decomposing into sand containing fragments of undecomposed felspar at lower altitudes than 14,000 feet, and the very common association of undecomposed felspar with other indications of an extreme climate justifies us in looking on it by itself, as an indication of a cold climate. In the present case independent evidence is also available, and the occurrence of a glacial epoch at the close of the Cretaceous or early in the Eocene period may be looked upon as extremely probable if not actually proved.

Original extent of the Indus Tertiaries.—Both Dr. Stoliczka and Mr. Lydekker have regarded the present extent of these beds as marking very closely their original extension, but as the evidence appears to me hardly to support this conclusion, and as the question is one that has an important bearing on the theory of the Himalayas, it will be well to enquire into the matter more fully than has yet been done.

As regards the north-eastern and north-western boundaries, they most distinctly mark the original limit of the lower beds of the series, for these can be seen to abut against the syenite of the Ladak range. On the south-west the beds have suffered much disturbance and the boundary is not one of original contact, so that there is no direct proof that the Tertiaries may not have extended far to the south. Nor does it follow, because the original extension of the lower group to the northwards is closely marked by its present limits, that the upper members of a series many thousands of feet in thickness were similarly limited in their extension.

With regard to the volcanic beds there are ample indications of a much larger area having been covered by them than is now the case. Not only are intrusive masses of pyroxenic trap, evidently of the same age as the Tertiary volcanics, found as far south as the Tso Morari and as far north as Shushal, but Mr. Lydekker has recorded the occurrence of a large outlier of the tertiary traps in central Zánskár;[1] this was not examined *in situ*, and it is uncertain whether they belong to the bedded volcanic series or are intrusive. If the former, their occurrence on beds of Jurassic age, without the intervention of the lower group of the Indus Tertiaries, would point to an overlap and limitation of the series in a southerly direction. But if the Zánskár outlier is intrusive, then it is probably only the core of one of the old Tertiary volcanoes.

From the above considerations it will follow that the supposed original limitation of the Tertiaries to the narrow region they now occupy is only proved in the case of the lowest group, and then only of the north-western and north-eastern boundaries; while as regards the south-western boundary and the volcanic group and the beds above it there are distinct indications of an original greater extension, and there is only negative evidence against their having been originally continuous with the Eocene beds of Chang-chengmo and the outer Himalayas.

Origin of the Rupshu Lakes.—It has been usual, since the publication of Mr. Drew's paper, to ascribe the origin of these lakes simply to the damming of river valleys by the fans of their tributaries. The barriers now visible are certainly talus fans, and these must extend to some depth below the former water-levels of the lakes; in some cases it may be that they form the entire barrier.

Yet it is not easy to understand how a lake could be formed in this manner; it would certainly be more natural to suppose that the main stream would be able to keep its channel open. There is however one way in which these lakes might be directly formed by talus dams and yet the ultimate cause be very different. If we suppose that any portion of a river valley were elevated more rapidly than the rate of erosion of the river,—a not very difficult supposition in so rainless a country,—the barrier so raised would react up stream and cause the formation of a sloping surface of river gravels. If then for some distance the configuration of the river valley was such that but little débris was shed into it and below this region the amount of débris

[1] Mem. G. S. of I., XXII, 116.

suddenly increased, it is quite conceivable that the rock barrier lower down might prevent this being carried away as fast as it was shed and so a talus dam formed across the valley.

There is one fact about the lakes which is difficult to reconcile with the theory that they are due to talus dams formed under climatic conditions differing from the present, and that is the very various degrees of dessication they present. The Hanle lake is now quite dry.[1] The Lingzitharig lake is almost dried up, the present area of permanent salt lake being less than one tenth of the original area. The salt lake of Rupshu occupies one eighth of its original extent,[2] the Pangong lake about one half, while the Tso Morari has contracted but one fifth and now has at least four fifths of its original extent.[3] Had the lakes all been formed at one period they would hardly exhibit these extreme variations in their degree of dessication, and this renders it more probable that some explanation such as I have proposed is the true one, as this would allow of the lakes having been formed at different periods, and of their consequent varying degrees of dessication.

Before leaving this subject it may be well to suggest that the gradual and progressive drying up of Ladak appears to me to have been a direct result of the gradual elevation of the Himalayas which in course of time cut off a larger and larger proportion of the moisture coming from the South.

Lake Basin and Karewahs of Kashmir.

The only two hypotheses which appear to have been suggested with regard to the orgin of the Kashmir Valley and more especially of the Karewahs are (1) that the dam was a glacier descending into the Jhelum valley, (2) a talus fan similar to the supposed barriers of the Rupshu lakes. The more obvious hypothesis that it was a rock barrier since cut through appears to have been regarded with but little favour.

In considering this question it is necessary to bear in mind that, though the largest and best known, Kashmir is not the only alluvial valley within the limits of the Himalayas. On the contrary it may be stated as a general rule that alluvial deposits of varying extent may be found in every river valley above where it enters what can be shewn to be a region of special elevation. The only explanation of this peculiarity seems to be in the supposition that during the elevation of the Himalayas there have been times when the rocky bed of a river has been elevated more rapidly than it could erode its channel and thus a deposit formed above the barrier. A similar explanation I believe to be the true one in the case of Kashmir and the greater extent of the valley to be in part due to its drainage escaping across the junction of the Pir Panjal and Hagara systems of disturbance, a region which may well have been exposed to more repeated and extensive upheavals than other parts of the Himalayas.

The principal reason why other hypotheses have been adopted appears to be the supposed lacustrine origin of the Karewahs. This however I find to be extremely doubtful. In many places beds of indubitable lacustrine origin may be found among the Karewahs, but the bulk of them are plainly of subaerial origin; just as at the present day alluvium is being deposited subaerially over large areas in the valley,

[1] Mem. G. S. of I., V, p. 130.
[2] Drew; "Jummoo and Kashmir," p. 398.
[3] Op. cit., p. 305.

but here and there, in hollows left by irregularity of deposition of the alluvium, true lacustrine deposits are being formed. It seems probable that while nearly every part of the valley was at one time or another occupied by a sheet of water there never was at one time a lake extending over the whole area of the valley.

Geology of the road from Kashmir to Chamba.—This is the only part of my route which crossed entirely new ground and will consequently be described in greater detail than the rest.

Leaving the Noroboog valley I marched up the Rajpáran valley and crossed into the drainage area of the Wardwán by the Chingam pass. The rocks up to this belong to the "Panjal system" of Mr. Lydekker except near the pass where quartzites occur apparently belonging to the Kuling series, and about four miles west of the pass there is an exposure of pebble slate with black carbonaceous rock.

The head of the valley leading down to Shingam (Chingram) is excavated on an anticlinal. At the base are slates, and above these come quartzites interbedded with some black carbonaceous bands and volcanic beds. At one spot, in the second tributary stream flowing from the south, I was fortunate enough to obtain some fossils which have not yet been examined in detail but appear to be of Kuling age. It is noteworthy that here they occur well below the great development of the volcanic beds, unless there is a very complicated inversion on both sides of the valley of which I found no proof.

A curious feature may be observed near the head of this tributary. On the hill side there is a sudden step or bank, commencing gradually and reaching a height of about six to eight feet; it runs along the hill side with a general course to W. 15° N., coinciding with the strike of the beds, but V-ing to the south in the valleys. It crosses the head of the next tributary, and in two of the minor drainage depressions which are not large enough to have a defined stream-bed, it has formed small hollows in which water appears to rest after heavy rain. On the watershed between the Shingam and Rajparan drainages it appears as a sudden step on the ridge, rendered more conspicuous by a talus bare of vegetation which contrasts strongly with the grass-clad slopes on either side.

Westwards from the ridge it can be traced as a sudden step, or elevation on the down hill side, running across an old moraine deposit which once formed the bed of a glacier, and on this there is a small pond naturally dammed by the elevation. I was not able to trace the full extent of this feature owing to clouds but it appears to vanish about ½ mile west of the watershed.

The only cause to which I can ascribe this is the actual appearance of a fault at the surface. I have already noticed a much more conspicuous instance in the hills south of the Giri valley between old Sirmur and Nahan, but it may be noticed that in the present case the fault is a normal one, *i.e.*, it hades to the downthrow, while the Sirmur fault follows the almost invariable rule of Himalayan faults and is 'reversed.' The feature I have described is of recent origin as is shewn by the little effect that denudation has had on it, as well as by the manner in which it traverses what appears to be the bed of an old glacier. The fact that it has in one place been able to form a permanent pond points to the sudden origin of the feature, which probably accompanied one of the violent earthquakes which are known to have affected Kashmir in the past.

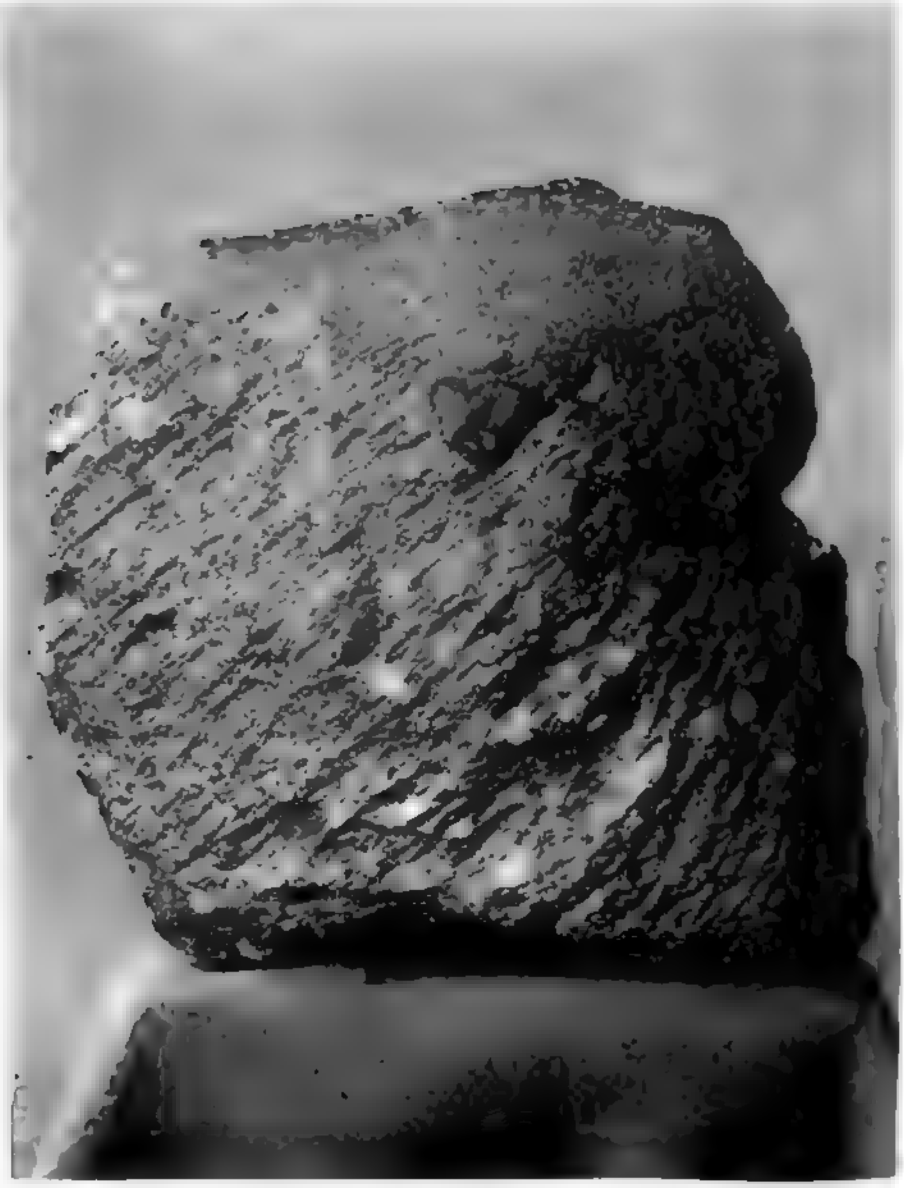

Photo-etching. Survey of India Offices, Calcutta, January 188

SAND-SCULPTURED QUARTZITE CONGLOMERATE, RAJPUTANA.

Descending the Shinton valley, slates continue with a high dip varying in direction between north and east, but towards Mogalmaidan they become schistose and garnetiferous, while all the streams leading down from the north contain boulders of gneissose granite.

From Mogalmaidan to Kishtwar mica and hornblende schists dip at high angles with a strike which has bent round to north and south, varying however up to 15° on either side, but usually not more than this.

Beyond Kishtwar a true gneiss series comes in suddenly, the junction with the schists being hidden by recent deposits. The gneiss has a general dip to south-west, and the Chenab flows along the strike and apparently close to the boundary between the gneiss and the overlying schists. In the Wariri valley a quantity of blue kyanite occurs in the gneiss by the road side and the same mineral is seen at intervals as far as Kandni.

Beyond Kandni the dip of the gneiss gets irregular and turns ultimately round to north-west. At the 'Khar gad,' schists come in, and no more gneiss is seen till above Nandan; on the road to Joru, a band of gneiss or gneissose granite was crossed.

The gneiss seen in the Chenab valley was the true bedded gneiss such as is seen on the Babeh pass section and not a gneissose granite. The junction with the schist series could not unfortunately be observed on a traverse, and I am at present uncertain whether there is a gradual transition or unconformable break.

In the valley crossed by the road a few miles before reaching Badrawár felspathic rock again appears underlying the schists. What was seen was all very decomposed, so its true nature was not determinable and I am not certain whether it is a true gneiss or a metamorphosed arkose rock. To a slight degree it resembled the latter, but it is altogether more probable that it is either a true gneiss, or gneissose granite. The dip of the beds is to north-east at 30° to 40° on the average and the whole termination of the spur is gneiss.

The rocks composing the ridge crossed between this valley and the town of Badrawár are schistose slates, so much less metamorphosed than those to the north and exhibiting so sudden a change that it is probable they are brought in by a fault.

At Badrawár innumerable blocks of gneissose granite may be seen, which have come from the west down the streams draining from the Kund Kaplas, but the rocks *in situ* as far as Tenála were grey slates dipping north-eastwards. From Tenála on, my route has already been described by Colonel McMahon, and on a mere traverse I saw nothing of importance to add to his description.

Note on Blown-Sand Rock Sculpture; *by* R. D. OLDHAM, A.R.S.M., F.G.S., *Deputy Superintendent, Geological Survey of India.* (With one plate.)

There is a very general impression that the striated surfaces produced by blown-sand are similar to those produced by glacial action, and when pebbles

shewing what are believed to be glacial striæ were lately sent to Europe from the boulder-bearing beds at the base of the Speckled Sandstone series of the Salt Range, suggestions were hazarded that they might have been produced by the action of blown-sand, yet so far as my experience goes, and as far as I can compare it with the published accounts of the observations of others, there is no real similarity between the effects of two such different agencies.

In the Desert region between the Aravalis and the Indus there are many opportunities of studying the effect of blown-sand, and during the season of 1886-87 I was able to collect some specimens exhibiting its peculiarities. One of these is depicted in the accompanying plate.

The principal characteristic of a surface smoothed by blown-sand lies in numerous broad and shallow grooves, deepest at the end from which the wind blows and growing shallower as they advance, giving the surface an appearance of having been roughly dressed with a carpenter's gouge. The scale of these grooves varies largely; on the surface of the limestone plateau near Jessalmer they are two or three yards long and four to six inches broad, on quartzite boulders or the hard glassy sandstone which occasionally occurs they are no larger than those depicted in the plate. This form of surface does not result from want of homogeneity of the rock for it is exhibited alike by the homogeneous limestones of Jessalmer and by pure quartz pebbles,—in the latter case, however, very obscurely, as might be expected, considering that the rounded sand grains can have very little erosive action on quartz. In the specimen of grit and conglomerate drawn, there are of course variations of texture, but these do not appear to have influenced the sculpturing which traverses the matrix and the enclosed pebbles indiscriminately.

Apart from this peculiar sculpturing the nature of the polish imparted to all hard rocks and pebbles exposed to the drifting sand is peculiar; all are highly polished, and where, owing to the disintegration of a conglomerate, the ground is covered with pebbles, they glisten in the sun in a manner that makes it painful to travel over them. This polish is however very different to that of a lapidary and rather resembles what would be produced by oil or grease. The polish sometimes seen on a glaciated pebble, on the other hand, resembles that produced by a lapidary; for all the irregularities of the surface are rubbed down, while the sand-blast polishes all the little irregularities of the surface, alike on eminence and hollow.

Re-discovery of Nummulites *in* Zánskár, *by* TOM. D. LA TOUCHE, B.A., *Deputy Superintendent, Geological Survey of India.* (With one plate.)

In Vol. XXII of the Memoirs, Geological Survey of India, at page 115, under the heading 'Reputed Tertiaries in Zánskár,' mention is made of certain nummulites, said to have been obtained by Dr. T. Thomson in 1852 from the Singhe lá, on

the road between Khalsi on the Indus and Padam in Zánskár, which nummulites were described by MM. D'Archiac and Haime in 1853 as N. raymondi (*ibid.* p. 11). The writer of the Memoir goes on to say: " The majority of the rocks on the Singhe lá consist of dolomites, limestones, and slates of mesozoic age; and as tertiary rocks have not been detected among them, the reputed origin of these nummulites must be regarded as open to a very strong element of doubt;" and suggests that they may have been obtained from a pass with a similar name, the Shingo lá, between Leh and Skiu, on which nummulitic rocks are plentiful (*ibid.*, p. 107) though, " as Dr. Thomson did not apparently traverse this route, it seems doubtful if this solution of the difficulty can be admitted."

Having recently had occasion to cross the Singhe lá (Singala of Quarter Sheet, 45 S.W. of the Atlas of India, in approximate Lat. 33° 58′ N., Long. 76° 58′ E.), I made a search for these nummulites, and was fortunate enough to find them, thus confirming the accuracy of Dr. Thomson's statement. Moreover, I was able (the pass and surrounding hills being almost free from snow) to trace the fragments of rock in which the fossils occur on the pass to their source, and to make some observations on the relations of the nummuliferous rocks to the underlying mesozoics.

I first came upon the nummulites at Linshot, a village at an altitude of 12,850 feet, lying on the southern slopes of the range crossed by the Singhe lá, and about 5½ miles to the west of the pass. Here they occur in numerous large boulders of limestone, embedded in the drift with which the valley is partially filled. Some of these boulders are of very large size, one measuring 40 feet by 20 feet in diameter, and are generally crowded with nummulites. They have evidently been carried down from above the precipitous scarp, north of the village, probably by a glacier, though at the present day there are none on the southern side of this range. The rock containing the nummulites is a very dark grey limestone, weathering to a sooty black colour, and giving a strong fetid odour when struck or broken; it is traversed by numerous thin veins of calcite.

Between Linshot and the Singhe lá fragments of the same limestone, filled with nummulites, are very numerous in the talus along the foot of the scarp to the north, especially in the valley in which the village of Chunpa-do-Goma is situated, where the talus is almost entirely composed of them. Blocks of grey quartzite from the underlying mesozoics, forming the base of the scarp, are also very common. Fragments of the nummulitic limestones continue to be found across the Singhe lá in the talus from the cliffs to the west of the pass, but none in that on the east; and to the north as far as the large side stream, joining the main valley about halfway between the pass and Phothoksar. This stream drains the northern side of the range between the Singhe lá and Linshot. Further north than this, as far as the Spangthang valley above Honupatta, west of the Sirsa lá (Sirsirla), beyond which I did not go, I could find no trace of the nummulites.

The rocks from which these fragments have been derived thus appear to be confined to the higher portion of the range immediately west of the Singhe lá. Owing to want of time, I was able to ascend the range at only one point, *viz.*, to the peak marked Z^4 on the map; here, at an altitude of about 18,500 feet[1] at the base of

[1] Water boiled at 179·9° F, and on the pass (16,601 feet according to the map) at 183·3° F, a difference of 3·4°, which corresponds to about 1,900 feet difference in altitude.

two precipitously-scarped masses, rising to 500 or 600 feet higher, and forming the summit of the peak, I found nummulites *in situ*, and numerous fragments crowded with them fallen from the cliffs above. These two masses are built up of layers, from a few inches to over a foot in thickness, of the same black fetid limestone that is found in fragments in the talus below containing nummulites; the beds dip inwards from the north-east and south-west respectively at an angle of about 20°, forming a shallow synclinal with its axis directed downwards towards the south-east, so that the same limestones occur at a much lower level than in the peak, at the top of the scarp running west from the pass towards Linshot.

It was difficult to make out the relations of the nummulitic limestones with the underlying rocks, owing to the manner in which the hill-sides below the peak are smothered in talus, outcrops of the rocks beneath only showing through in detached patches; and this difficulty was increased by the sharp folding which the whole of the rocks have undergone. The limestones, however, appear to rest conformably on thick beds of grey quartzite, which in turn are underlaid by shales forming the pass itself. To the east succeed mesozoic limestones and slates, much folded and inverted, so that at the pass they appear to be resting on the shales. These relations I have attempted to shew in the accompanying section, but am not inclined to guarantee its accuracy in every detail.

The apparent conformity between the nummulitic limestone and the quartzite may have been superinduced by folding subsequent to the deposition of the tertiaries, for in the Indus valley the nummuliferous beds occur in the higher zones of the series, and there are indications of an overlap on the southern border of that area (Mem. G. S. of I., Vol. XXII, pp. 107 and 110).

It is thus proved beyond doubt that in middle eocene times the southern shore line of the tertiary sea (occupying what is now the Indus valley) did run out far to the south, as Mr. Lydekker supposes may have been the case (*ibid.*, p. 120), and included the Singhe lá. How much further to the south this sea extended there is no evidence to shew, as no nummulites have yet been found on any of the passes between the Singhe lá and the great range south of Zánskár; but the absence of conglomerates, such as are found in the Indus valley below the nummulitic beds, beneath the limestones of peak Z^4, would seem to shew that the shore-line was at a considerable distance. That it was not connected in this direction with the sea occupying the basin of the outer hills, seems fairly certain, for in the lower Chenab valley, where two large inliers of Zánskár rocks occur, Murree sandstones are found immediately in contact with the mesozoics of the upper and nearer inlier, while in the lower and more distant one nummulitic limestones intervene, thus indicating a shore-line to the north in that area in middle eocene times (*ibid.*, p. 92).

This confirmation of Dr. Thomson's discovery affords further evidence of the enormous earth movements that have taken place in the north-west Himalayan area since early tertiary times, whereby marine strata have been elevated more than 18,500 feet above the present sea-level. As far as I am aware, this is the greatest altitude at which marine fossils have hitherto been obtained *in situ*.

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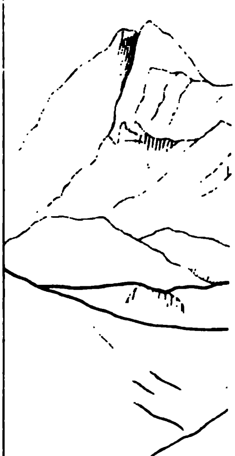

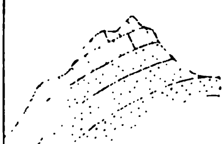

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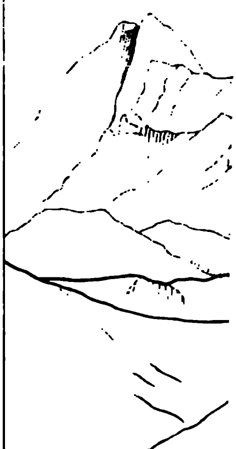

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Notes on some Mica-traps from Barakar and Raniganj, *by* PRAMATHA NATH BOSE, B.SC. (Lond.), F.G.S., *Deputy Superintendent, Geological Survey of India.*

The specimens described below were collected during a short excursion with the Director to Barakar and Raniganj towards the end of last August. The time at our disposal was too short and the weather too unpropitious for a systematic study of these highly interesting rocks; and my only reasons for publishing the following rough notes, based on three specimens, all more or less decomposed, are the scant attention which their petrography has received hitherto, and the possibility of its not receiving further attention at least in the immediate future. Dr. Blanford described them twenty-eight years ago in the following terms [1] :—

"The trap forming the various dykes differs greatly in mineral character. It is generally more or less decomposed, and frequently contains a whitish micaceous mineral, somewhat resembling margarodite in little rounded masses. In many cases it contains black mica."

And this is, I believe, the only description we have of the rocks.

The mode of occurrence of the mica traps, and their probable age, have been discussed by Dr. Blanford.[2] They occur as dykes and intrusive sheets, altering the rocks in contact, and often ramifying through the coal. The action of contact metamorphism on the coal has almost invariably resulted in the production of a columnar structure in it. The columns are usually hexagonal, and invariably perpendicular to the direction of the dykes and sheets. Sometimes they radiate from a central core composed of the intrusive rock. Some beautiful examples of the radiating arrangement were seen at the Laikdih quarries near Barakar. The contact coal has been hardened, and is left in the pits and quarries, being considered worthless as fuel.

The following assays of two specimens of contact, columnar coal, made by Mr. Hira Lal in the Survey laboratory, will shew their composition.

An analysis of a good sample of the normal Barakar coal is also given for the sake of comparison.

	Columnar coal.		Normal coal.
	No. 1.	No. 2.	
Moisture	3·38	2·98	2·48
Volatile Matter (exclusive of moisture) . .	9·02	7·62	28·72
Fixed Carbon	68·60	78·00	60·20
Ash	19·00	11·40	8·60
	100·00	100·00	100·00

[1] Mem., G. S. I., Vol. III, p. 142. [2] Op. cit., pp. 141, &c.

The contact coal burns very slowly. It is not, as has been observed above, raised at present.

The dykes and intrusive sheets are, as observed by Dr. Blanford, "almost confined to the Lower Damadas. A few instances, however, occur in the Raniganj Series." The specimens from the Raniganj mine described below are from dykes which have intruded through the latter.

With regard to the geological age, Dr. Blanford saw "good reason for supposing that these intrusions may have been contemporaneous with the great volcanic outbursts, of which evidence exists in the Rajmahal hills;" and the balance of probabilities appeared to him to be in favour of their being of Rajmahal (Upper Gondwana) age.[1]

The intrusions from which the following specimens were obtained are all very small, not exceeding six feet across.

As far as I am aware, Mica-traps have not been described from any other part of India. They are found intrusive in the older Palæozoic rocks in England (Westmoreland and Yorkshire), in the Southern Uplands of Scotland, and in several localities in Ireland. They are also met with in the Channel Islands, Saxony, the Vosges Mountains, Baden, North-Western and West Central France, and in the Pyrenees.[2]

No. $\frac{8}{384}$ (Laikdih quarry, near Barakar), sp. gr. 2·77. Grayish rock with abundant flakes of biotite visible macroscopically; effervesces with hydrochloric acid. Fracture, uneven.

Under the microscope, the ground-mass is found to be microcrystalline. There are abundant rod-like, translucent microlites, some of which probably belong to plagioclase. There is also some apatite. Minute specks of viridite abound; and some cloudy dark-brown, opaque specks and patches (decomposed mica and ferrite), and a little magnetite also occur. There are, besides, irregular, nebulous, finely grenular, greyish patches which shew strong double refraction, observable with the analyser alone. Some of these patches occur in association with secondary quartz presently to be mentioned. From their behaviour, they appear to me to consist of calcareous matter—the result, in all likelihood, of decomposition.

There are, in the ground-mass, polygonal or rounded spaces, in which shadowy outlines are discernible in transmitted light; the finely granular substance just mentioned bays into some: and magnetite is sometimes found enclosed. With polarised light some of these spaces are clearly seen to be filled with quartz (secondary), exhibiting a mosaic play of colours, and others with a zeolite shewing beautiful radiating structure. The two (quartz and zeolite) are in some cases associated together.

Some of the biotite crystals are large, which are visible macroscopically, but the majority are minute, visible only under the microscope. They exhibit strong dichroism. The larger crystals have frayed edges.

There is no well-developed felspar, nor is any pyroxene or amphibole visible.

[1] Op. cit., pp. 144-145. Colonel McMahon, from a lithological study of the Deccan and the Rajmahal traps, suggests the possibility of their being contemporaneous (Rec., G. S. I., Vol. XX, p. 110).

[2] Bonney, Q. J. G. S., Vol. XXXV, p. 165.

If the felspar microlites mentioned above really belong to plagioclase, the rock may be called *kersanton*. There is present 48·48 per cent. of silica according to an analysis made by Mr. T. R. Blyth in the Survey laboratory.

No. $\frac{8}{283}$ (Raniganj Mine). Sp. gr. 2·45. Greyish-green compact rock; effervesces, but very slightly, with hydrochloric acid. No crystals are visible macroscopically.

Under the microscope the ground-mass is seen to be microcrystalline. Minute crystals of biotite are very plentiful. It is the predominant mineral, as in the last specimen. There are some lath-shaped, badly-developed crystals of plagioclase. They occur as single individuals, and exhibit no twinning. A few crystals of hornblende occur, which shew characteristic cleavage, and marked pleochroism with polarised light. In these a granular or fibrous greenish decomposition-product sometimes appears. It is probably identical with a similar mineral which is rather abundant and which has, as a rule, a rather well-defined contour. If so, there can be no doubt that this mineral is the result of decomposition of the hornblende. With a single Nicol, the mineral in question shews very feeble dichroism, or none at all; in all probability it is chlorite. Greyish cloudy patches similar to those which have been described as occurring in the last specimen occur, but are not so abundant. Sometimes they shade off into the greenish decomposition-product just mentioned There is a little magnetite. The percentage of silica present in the rock, determined by Mr. Blyth in the Survey laboratory, is 51·68.

The rock may be called *kersantite*, if the presence of hornblende be a sufficient ch racter to distinguish it from the last specimen.

No. $\frac{8}{282}$ (Raniganj Mine). A greyish-brown, mottled, vesicular rock. No crystals are visible with the unassisted eye.

Under the microscope, the ground-mass is seen to be microcrystalline. It is crowded with minute, badly-developed crystals of biotite. There are some long lath-shaped crystals of plagioclase, all of which appear to occur as single individuals, as in the last specimen. Greenish specks and patches abound, as in the last specimen, but no hornblende is observable. There is a little magnetite and some secondary quartz. The percentage of silica present in the rock, determined by Mr. Blyth in the Survey laboratory, is 57·88.

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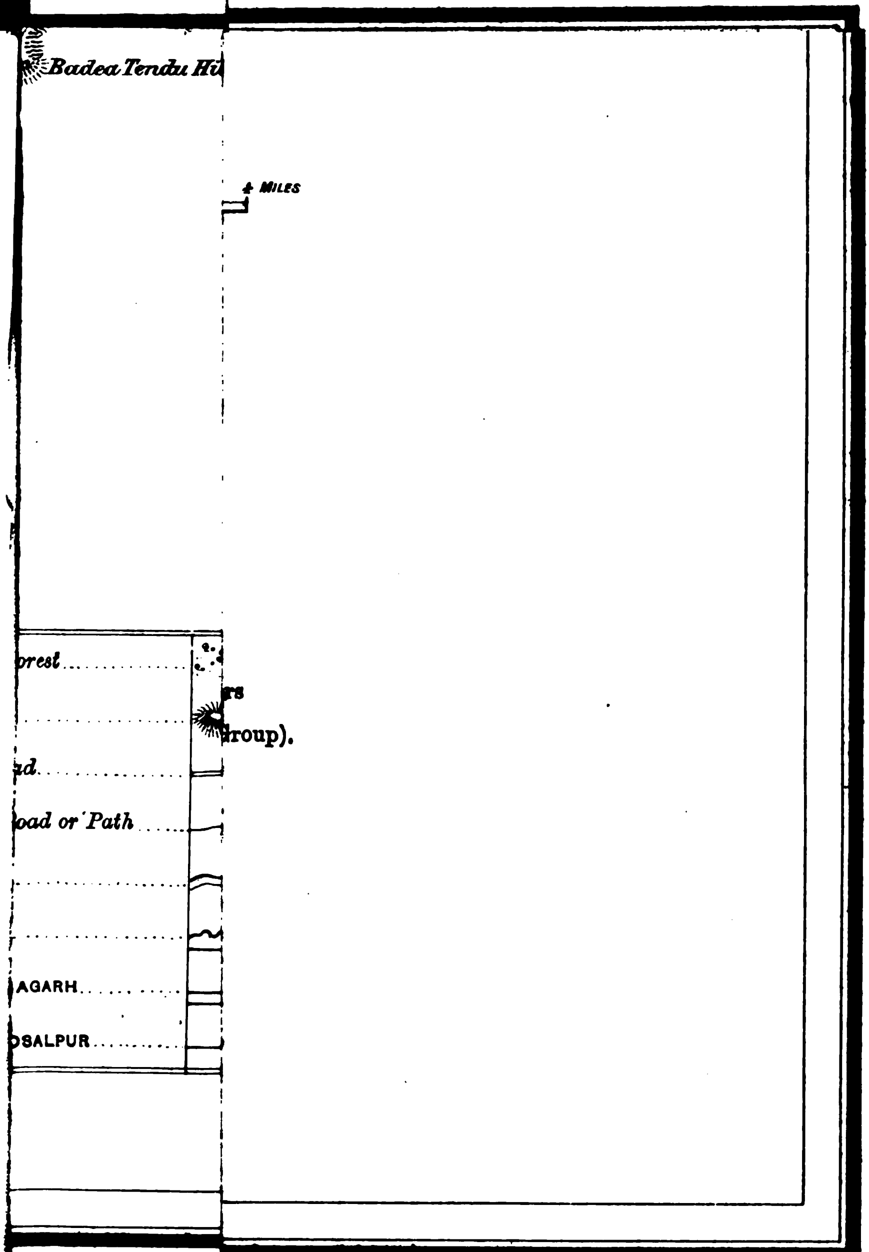

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Ten cut and polished gems:—Yellow topaz and tourmaline from Brazil; zircon (hyacinth) from New South Wales; white topaz, blue spinel, and chrysoberyl, from Ceylon; rubellite, phenakite, and green garnet, from Russia; and peridot from Sicily. From James R. Gregory, Mineralogist, London, by exchange.

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„ Carbon and certain compounds of carbon, treated principally in reference to heating and illuminating purposes. 8° Pam. London, 1874.

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